This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

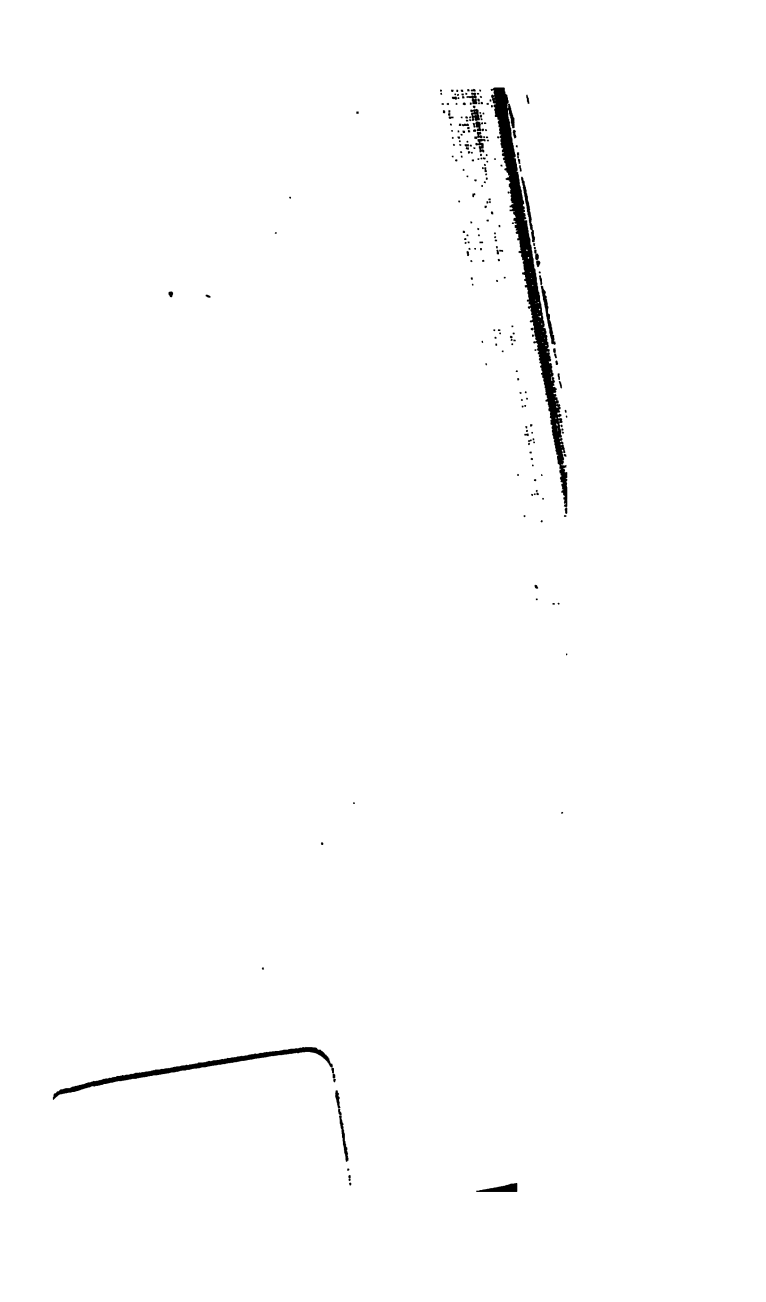
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

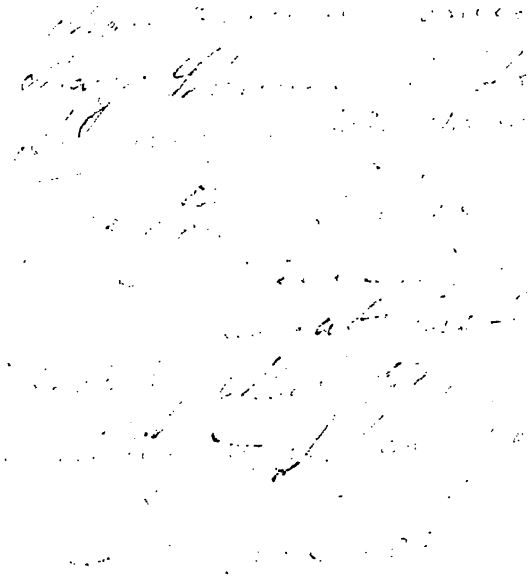
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NYPL RESEARCH LIBRARIES
3433 06909948 3





NATURAL PHILOSOPHY

FOR

BEGINNERS:

DESIGNED FOR COMMON SCHOOLS

AND FAMILIES.

BY MRS. PHELPS,

AUTHOR OF FAMILIAR LECTURES ON BOTANY, NATURAL PHILOSOPHY, CHEMISTRY AND BOTANY AND CHEMISTRY FOR BEGINNERS.

NEW YORK:

PUBLISHED BY F. J. HUNTINGTON AND CO.

174 PEARL STREET.

1840.

THE NEW YORK
PUBLIC LIBRARY
474377
ASTOR, LENOX AND
TILDEN FOUNDATIONS.
1909

ENTERED
According to the Act of Congress, in the year 1838,
F. J. HUNTINGTON AND CO.
In the Clerk's office of the Sonthern District of
NEW YORK.

STEREOTYPED BY
FRANCIS F. RIPLEY,
NEW YORK.

PREFACE.

The importance of early instruction in the first principles of Natural Philosophy, must be obvious to every reflecting mind. The attention of the young should be directed to natural operations; that thus the powers of observation and comparison may be developed and strengthened. Many a human mind fitted by nature for greatness, has passed through this life unnoticed and unknown, and even ignorant of its own inherent strength, because its faculties had never been called into activity by a right education, or developed by favorable circumstances. It must, however, be acknowledged, that it is not always in the "*school room*," that the mind shoots forth with the greatest vigor. Education, in the common use of the term, is too much encumbered with forms, and fettered by custom. However lightly, some may esteem the business of teaching, as fitted only for dull and plodding minds, it is yet true that no profession demands greater originality, more invention and quickness of apprehension, than this: and wherever we find a successful teacher, we may be assured that this success, is the result of a high order of talents. Such a teacher is ever laboring to throw off the incubus of *routine*, which is dangerous alike to teacher and pupil; he endeavors to give

variety and interest to his instructions; and is ever inventing methods to arouse and arrest the attention. Like the bee who gleans from every flower something for her hive, the teacher should collect from every accessible source, a fund of interesting anecdote, pleasing illustrations, and useful facts, to enliven and enrich his conversations with his pupils; then will they consider their school-hours, not only among their most profitable, but their happiest ones. The Author of this little book, after having spent many years of her life in teaching, and many in writing for the young, is more than ever impressed with a sense of the importance of interesting them in their scholastic pursuits. When a study like that of Natural Philosophy is, at the same time highly useful in itself, and of a nature to please the mind and awaken its dormant powers, we may well prize it as an important auxiliary in education. Nature, on all sides, offers to the parent and teacher, occasions for illustrating the principles of this science, whether walking, riding, sailing, or sitting by the fire-side. The mechanic's shop, the mill and manufactory, exhibit philosophical experiments on a large scale, and visits to them might give occasion for useful explanations.

It is important that the spirit of philosophical inquiry which manifests itself early in an intelligent child, should be encouraged and directed. His questions often involve important principles; habit has not yet rendered him familiar with natural phenomena, which excite no inquiry in older persons, because they are common. The accelerated motion of a stone roll-

ing down hill, the gliding of a sled upon the ice, the rebounding of an elastic ball, the action of the common bellows, or the spinning of a top, each may produce inquiries favorable for instruction in the elements of philosophy, and for inducing in the young mind the grand truth, on which religion, no less than philosophy is founded, that, for every thing there must be a cause, until we ascend to the *one great, First cause.* As soon as a child begins to ask, "what makes a gun shoot, an arrow fly, or a vessel sail; why the wind rushes in at an open door, and what makes the rain and the thunder," the business of teaching him philosophy should begin. If he is told only, that God does every thing, and is the cause of all the changes in nature, and, afterwards, learns that there are certain known causes which produce these changes, he very naturally begins to doubt; and confounding secondary causes with the primary one, may fall into the sceptical belief, that there is, in nature, a circle of causes, the one producing another, and sufficient to account for every thing without reference to the power of God.

We should, therefore, early accustom the young to reflect on secondary causes; we should teach them that though God directs every thing, his operations are conducted according to certain established laws, which in many cases, we are able to comprehend; so that when we speak of the cause of wind or thunder, we mean the secondary cause, believing, however, that God directs the thunderbolt by his omniscient mind, no less certainly, than that man aims the musket, the explosive force of whose discharge, philosophy can

explain. It has been said philosophically, as well poetically, in reference to the universe;

"Whose body nature is, and God the soul."

Moved by an impulse from this divine spirit, any portion of any domain of nature may become active, the inert matter which forms the human body is actuated by the mind within. If we cannot tell how the mind can move the muscles of the body, or how it can be in every place of this body at once, seeing through the eyes, hearing at the ears, and feeling the prick of a pin at any portion of its surface, shall we wonder that we cannot understand how God can, at the same moment, be in all parts of the universe, directing the operations of this vast body of which he is the *all-pervading mind?*

Though the volume of nature demands the first attention, yet it cannot be profitably studied without the aid of science, which has its divisions and outlines, and therefore the young need books, in which they may study them. The parent and teacher also, may find it convenient to have an assistant and guide. This little treatise is offered with the hope, that it may be found a useful and pleasant companion in the school-room, and by the fire-side. The parent or the common school teacher, who from want of early instruction, may feel himself an inadequate teacher of Natural Philosophy, will here find an assistant, and may, by its aid, be enabled to enjoy the satisfaction of both gaining and imparting knowledge.

CONTENTS.

CHAPTER I.—Introduction. Advantages of the study of Natural Philosophy..... 11

PART I.

MECHANICAL PROPERTIES OF SOLIDS.

CHAPTER II.—Matter. Space. Impenetrability. Extension 14
CHAPTER III.—Divisibility. Atoms. Porosity. Elasticity. Density..... 20
CHAPTER IV.—Inertia. Force. Gravitation 28
CHAPTER V.—Cohesion, or the power of solid bodies to resist pressure. Principles of Mechanics applied to architecture..... 31
CHAPTER VI.—Attraction of Gravitation..... 42
CHAPTER VII.—Centre of Gravity..... 45
CHAPTER VIII.—Power..... 53
CHAPTER IX.—Motion. Momentum. Motion downward. Motion upward..... 56
CHAPTER X.—Laws of Motion. Compound Motion. Composition of Forces. Projectiles..... 65

PART II.

MECHANICS.

CHAPTER XI.—Simple Machines. The Cord. The Lever. The Pulley..... 74
CHAPTER XII.—Compound Mechanical Powers..... 79
CHAPTER XIII.—Complex Machinery..... 84

PART III.

HYDROSTATICS, OR THE SUBJECT OF LIQUIDS.

CHAPTER XIV.—General Observations on Fluids..... 88
CHAPTER XV.—Mechanical properties of Liquids..... 92
CHAPTER XVI.—Comparative weight of Liquids..... 98
CHAPTER XVII.—Hydraulics, or water in motion..... 103
CHAPTER XVIII.—General Summary of Hydrostatics.. 107

PART IV.

PNEUMATICS, OR THE SUBJECT OF AIR.

CHAPTER XIX.—Air. Compressibility of Air. Effect of Heat upon Air. The Air-pump. Piston and Cylinder.....
CHAPTER XX.—Condenser. Experiments with the Air-pump. Experiments with the Condenser.....
CHAPTER XXI.—Barometer.....
CHAPTER XXII.—Pumps. Fire-engine. Intermitting Springs.....
CHAPTER XXIII.—Vapors. Gases.....
CHAPTER XXIV.—General Summary of Pneumatics..

PART V.

ACOUSTICS, OR THE SUBJECT OF SOUND.

CHAPTER XXV.—Sonorous Bodies. The Ear.....
CHAPTER XXVI.—Medium of Sound. Echo. Velocity of Sound.....

PART VI.

OPTICS, OR THE SUBJECT OF LIGHT.

CHAPTER XXVII.—Definitions. Diffusion of Light. Reflection and Refraction. Angles of Incidence and Reflection.....
CHAPTER XXVIII.—Mirrors.....
CHAPTER XXIX.—Refraction of Light.....
CHAPTER XXX.—Lenses. The Eye.....
CHAPTER XXXI.—Light and Shade. Imperfection of vision. Optical Instruments.....
CHAPTER XXXII.—Shadows. Decomposition of Light. Rainbow. Absorption of Light.....

PART VII.

ANIMAL MECHANICS.

CHAPTER XXXIII.—Mechanism of the Human body..
CHPATER XXXIV.—Tendons, or Sinews and Muscles..
VOCABULARY.....

INTRODUCTION.

CHAPTER I.

Advantages of the Study of Natural Philosophy.

1. The objects included in the study of Natural Philosophy are as extensive and varied as creation itself. Every thing which we can see or hear, has its philosophical relations; thus light, air, water, and all solid bodies, are the subjects of this science.

2. Man only, of all living creatures on the earth, appears to study into the philosophy of nature. None of the lower orders of animals have ever made any improvements or discoveries in science. Man alone is endowed with reason to study into the causes of things, and with language to convey his observations to others.

3. In a savage state, men think only of the means by which they may provide themselves with the necessaries of life. When the savage looks abroad upon the wonders of creation, he, no doubt, feels a desire to understand them; but there are some races of men who seem too indolent to cultivate their minds. They live and die with scarcely more knowledge than the brutes, enjoying only the gross pleasures of the senses, and wholly ignorant of the more pure and elevated enjoyments which spring from the enlightened and cultivated mind.

---

1. Of what objects does Natural Philosophy treat?
2. Who, alone, studies into the philosophy of nature?
3. Of what only do men think in a savage state?

4. When the Romans under Julius Cæsar, invaded Britain, the land of our forefathers, the inhabitants, as some historians tell us, lived in caves and holes in the earth; they went without clothing, and had no other food than roots, berries, and such fruit as the earth brought forth without cultivation.

5. But these ignorant British savages were always remarkable for their activity; and they no sooner witnessed the civilization of their Roman conquerors, than they were filled with zeal to improve their own condition. They have progressed in this work of improvement, so that in less than nineteen centuries they have filled their country with the most magnificent works of art, and extended their colonies and commerce to every corner of the globe.

6. Our ancestors, a little more than two hundred years ago, found this country in the hands of savages; but they brought with them the learning and improvements of civilized life, and taught them to their children.

7. But learning fifty years ago, was far less common than at present. A few were educated in colleges, and to these was communicated the knowledge, which then existed, of Mathematics, of Languages, and the *Belles lettres* or General literature.

8. Natural Philosophy had, for many centuries, remained much in the state in which the ancient Greeks and Romans left it. And Chemistry, Botany, and Mineralogy were scarcely considered as sciences, so little attention had been paid to the study of nature under her different aspects.

9. It is only within a few years, that books which

---

4. What was the condition of the Britains before the Roman invasion?

5. What was the effect of the Roman Conquest on the inhabitants of Britain?

6. In whose hands did our ancestors find this country?

7. What was the state of learning fifty years ago?

8. Had the study of nature received much attention?

lead the young to study the creation around them, have been put into their hands. Such books may be regarded either as reflecting mirrors, microscopes or telescopes which exhibit things under new or more striking aspects, and reveal to the mind relations and connexions which it had never before conceived of. In short, the student of nature sees with new eyes. Where before he groped in darkness, he sees light; where before he saw nothing, he now sees a beautiful and harmonious system of causes and effects, proclaiming the wisdom and powers of an unchangeable Creator.

10. *Observation* and *Experiment*, are the means which God has given man for the attainment of knowledge, and even the infant knows how to use them. The child begins to study philosophy almost as soon as he opens his eyes. He looks at objects as if he would understand their nature, and he is constantly making experiments upon his playthings, and all that he can get within his grasp.

11. Let the young continue to follow this early impulse of the mind to seek knowledge. In the study of Natural Philosophy there are important advantages. It leads to useful inventions; to the habit of observing and reasoning; it elevates and enlarges the mind, and gives the soul new and delightful views of the power and goodness of God.

---

9. What can you say of books that lead to the study of Nature?
10. By what means do we attain knowledge, and when does the child begin to use them?
11. What can you say of the study of Natural Philosophy?

PART I.

OF THE MECHANICAL PROPERTIES OF SOLIDS.

CHAPTER II.

Matter—Space—Impenetrability—Extension.

12. As in civilized society, there are *men*, and **laws**, by which these men are governed, so in nature, there are *substances*, and laws, by which these substances are regulated. Science, not only considers substances or *things*, but *general laws*, and the relations which bind substances together, or cause them to influence each other.

13. There are several departments of knowledge included under the general term, *Natural Science;* among these is Chemistry, which treats of the *interior structure* of bodies, and Natural History, which treats of their forms and external organs. Natural Philosophy, is also a branch of Natural, or, as it is sometimes called, Physical Science.

14. The term *Philosophy*, signifies a *knowledge of the reasons, or causes of things. Natural Philosophy,*

12. What does science consider?

13. What departments of knowledge are included under the term Natural science?

14. What does the term Philosophy signify?—What is Natural Philosophy?

is the science which treats of matter,—its properties and laws.

15. Many people are satisfied to live without inquiring into the reason of things which are daily taking place. How many there are, who see the sun rise and set, without ever thinking of the cause of this change! How many have never thought why a stone thrown upwards, falls again to the earth, instead of continuing to move in the direction first given it! How many who never think of inquiring into the properties of the objects around them;—who even view them with indifference, except so far, perhaps, as they supply some immediate bodily want!

16. All bodies are composed of *matter*. Matter is that which is manifested to our senses. All that we can see, touch or taste, are *material* substances. But some matter, is invisible, as air; if you move a fan briskly, you can feel the air; and, in various other ways, it may be proved that air, is as much a material substance as water, or wood.

17. *Space*, in common language, signifies *room*. Thus it is said, "there is no room or space in the carriage for another person," "there is no room in the tumbler for more water."

18. *Space may be either occupied or empty.* If a spoon be put into a tumbler full of water, it will displace, or cause to flow over, as much water as is equal to the bulk of the spoon; on taking out the spoon, water will rush into the place which it occupied. If, when the spoon was taken out of the water, the space it occupied, should continue vacant, such vacant space, would be *void*, or pure space, which is called, in philosophy, a *vacuum*.

---

15. Indifference of mankind about the causes of things?
16. What are all bodies composed of?
17. What is the meaning of space?
18. What is meant by space being occupied?—What is a vacuum?

19. There appears to be no vacuum in nature, but all space, as far as we know, is filled with something. Water fills all the cavities between stones, or earth, which exist in seas, lakes, rivers, and ponds; and air fills all cavities, which are not occupied by solid or liquid bodies.

20. The air around the globe, called the atmosphere, extends but a small distance in space. Between this and the moon, the sun, and the stars, we know not what substance may fill the immense expanse; but, as we find no vacuum on the earth, we have reason to believe there is none in regions beyond our atmosphere.

Impenetrability.

21. *Impenetrability* is that property of matter which does not permit two substances, at the same time to occupy the same space.

22. *No two substances can at the same time occupy the same space.* The pores of a dry sponge are filled with air; immerse the sponge in water, and the air will be displaced from the little pores or cavities of the sponge, and water will rush in to supply its place. Thus, if two persons at the same instant move their heads towards a certain point, they may come in contact, and each receive a blow; but one of the heads only, can be in a particular point of space at the same time.

23. *Sponge* is impenetrable. We will suppose you to hold, in your hand, a wet sponge; the water which

---

19. Is all space filled?

20. Is it known what fills the expanse between the earth and the heavenly bodies?

21. What is impenetrability?

22. Can two substances at the same time occupy the same space?—What example can you give?

23. Why is a wet sponge heavier and more bulky than a dry one?

now fills its cavities, or pores, has crowded out the air, which before filled them, and water being heavier than air, this wet sponge is much heavier now, than when it was dry. It is also more bulky, because the water has swelled out its pores, more than the air did.

24. *Wood* is impenetrable. A nail driven into a board, crowds the fibres of wood, so that, by being nearer together, they occupy as much less space, as is filled by the nail.

25. *Air* is impenetrable. When you move your hand through the air, you separate it, as you do water in moving your hand through that. You know that the *space* occupied by your hand on holding it in a basin of water, does not also contain water, neither does air remain in the same space occupied by another body, at the same time.

Extension or Magnitude.

26. *We can form no idea of any substance that has not dimensions; that is, length, breadth, and thickness.*

Every object on earth has its limits; thus we not only speak of the length and breadth of rivers and lakes, but of vast oceans. The earth itself, has its known limits of extension, and the body of air or the atmosphere which surrounds it, is proved to be but little more than forty miles in thickness.

27. *The limits of extension are called figure or shape.*

28. *The bulk or volume* of a substance signifies its *size*, or, in other words, *the space which it occupies.*

29. Two bodies of the *same shape*, may be very *dif-*

---

24. What examples can you give of the impenetrability of wood?

25. What examples can you give of the impenetrability of air?

26. What is meant by the dimensions of a substance?—Are all earthly objects limited?

27. What are the limits of extension called?

28. What does the bulk or volume of a substance signify?

29. Is there any difference between shape and bulk?

ferent as to bulk; as a round pebble, and the globe of the earth. Again bodies may be very *different in shape*, and yet *equal in bulk or volume.*

30. It may seem not easy to find out the exact bulk of an irregular shaped body, like a piece of sparry lime-rock; the only certain way of doing this, is to put it into water. Fill a tumbler quite full of water, into this, immerse a lump of spar, or any other mineral or substance, whose bulk you wish to ascertain; water will thereupon flow out, or run over, exactly in proportion to the bulk of the mineral or substance so immersed; thus we say so much water is *displaced*, and if the vessel in which a substance is immersed be not full, the water that is displaced, will rise without overflowing.

31. You may then try another lump of mineral, or other substance of a very different shape, and if the quantity of water, which flows over, or is displaced, be in both cases equal, you may be certain they are of the same bulk, that is, that they occupy just the same portion of space, though one may be of an exceedingly irregular form, and uneven surface, while the other may be perfectly smooth, and round or square. As you advance in your study of Natural Philosophy, you will find, that on this fact, is established a rule for finding the *comparative weight* of different bodies, or what is called their *specific gravity.*

32. The exact bulk of a regular body, may be determined by a rule of arithmetic. When the length and breadth of such regular body are known, multiply the one by the other, and the product will be the *bulk* or *solid contents* of such body.

---

30. How can you find the bulk of an irregular shaped body?

31. How can you find the comparative bulk of substances of different shapes?—What rule is established on the fact that bodies of equal bulk displace an equal quantity of water?

32. By what rule can you determine the exact bulk of a regular shaped body?

33. The length and breadth of an irregular body, cannot be found by measurement, because of the inequality of its surface, and variety of its parts. The exact bulk of such a body, can only be ascertained by weighing it in water. If it weigh just the same in the water as out of it, one ounce of the body weighed, is equal in bulk to one ounce of water; but if a body, weighing in the air, *two* ounces, weigh in water but one, it is then *twice as heavy as water*, and *four* ounces of the latter would be of equal bulk to the body weighed.

34. *Impenetrability* and *extension*, are called *essential* properties of matter, because we cannot conceive of any matter which does not possess them. There are also, *general properties* of matter; so called, because they exist, in a greater or less degree, in most substances; of these, are divisibility, compressibility, elasticity, &c. *Secondary properties* of matter are such as are sometimes possessed by a body,—at other times wanting; they are color, hardness, fluidity &c.

---

33. Why cannot the length and breadth of an irregular shaped body be found by measurement?—How can the exact bulk of an irregular shaped body be found?

34. What are the two essential properties of matter?—General and Secondary properties.

CHAPTER III.

Divisibility—Atoms—Porosity—Compress Elasticity—Density.

Divisibility.

35. We know of no substance which ma broken, or divided into parts. Infant phi delight to make their little experiments upon bility of matter. The first trial children mak toys is to see if they will break.* The mos child would probably be quieted for a mom nurse would give it, for playthings, a "hami looking glass."

36. *Divisibility may be either chemical or cal.*

Let a piece of chalk be broken to pieces hammer, and pounded into dust-like particle these particles is composed of several elemei chemical means alone can separate.

* A writer on philosophy seems to think that a chief done by children in tearing and breaking things of philosophical inquiry. He ascribes to this dispos mind to prove the divisibility of matter, the fondness for splashing water about, throwing dirt, and playing in phrenologist would tell us that the breaking of the toy things within the child's grasp was owing to his *dest* and that throwing water, dirt &c. was on account of *iveness.*

35. Is there any known substance which may not be
Fondness of children for making experiments on divisi
36. What kinds of Divisibility can you mention?—
the elements of chalk be divided?

37. We will now explain what is meant by *chemical division ;*—chalk is *carbonate of lime*, and is composed of *carbonic acid* and *lime* united. Heat, which is a chemical agent, can expel the carbonic acid, and the lime will then be left. Again, lime is a compound of *oxygen* gas and a metal called *calcium ;* a second chemical process is necessary to decompose lime, or to separate those two substances ; after which, as they are simple or elementary, they cannot be reduced to any more simple state.

38. *Mechanical* division is performed by means of breaking, pounding, filing and various other methods. Chalk may easily be reduced to powder ; iron requires great force to separate it into fine particles, and diamond is still harder than iron.

39. Nature presents us with examples of very great divisibility of matter. The *perfume of the rose* is a portion of the flower itself, which passes off in various directions, and thus comes in contact with our organs of smell. The *threads of the spider's* web, which seem to the naked eye to be as fine as possible, are yet found to be composed of a great number of smaller threads.

40. Leeuwenhoeck, a Dutch philosopher, examining with a microscope or magnifying glass, a young spider no bigger than a grain of sand, found that it would require four millions of the strands of which it made one thread of its web to form thread as thick as a hair.

---

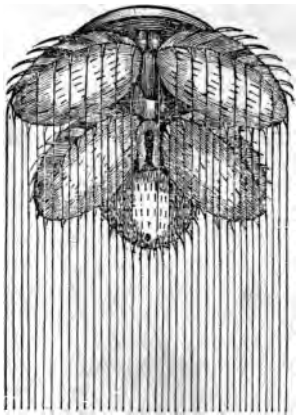
37. Of what substance is chalk composed ?—How can carbonic acid be separated from lime ?—By what means can the two substances which compose lime be separated ?

38. How is mechanical division performed ?

39. Give some examples of the divisibility of matter, which appears in nature.

40. Experiments of a philosopher upon a spider's web.

Fig. 1.



41. The figure shows a small spider, as it appears when seen with a microscope; the strands are represented by black lines. Each strand is reckoned to contain one hundred or more fine threads, a hundred of which unite to form one single filament of gossamer, or spiders's web.

42. You are not to understand that the philosopher actually twisted the threads, in order to prove what he asserts; he had invented a method of calculating, by which he was able to tell with great accuracy, the comparative sizes of very small objects.

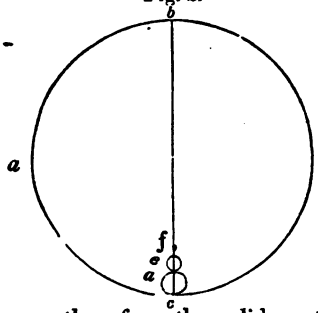
43. We will endeavor to give you some idea of this method. He says "I lay it down as a position that I can see the space occupied by a grain of sand magnified to

---

41. Explain the figure.
42. Did the philosopher prove what he asserts by twisting the threads together.
43. By what method of calculation did he proceed?

that represented by the circle, *a*, *b*, *g*, *c*. Next, I suppose that I observe, within this space, an animalcule* swimming or running, and appearing of the size represented at *a*. Taking the measure of this, by my eye, I conceive the axis or thickness of the animalcule thus pictured at *a*, to be a twelfth part of the axis of the grain of sand represented by *a b g c*; therefore, the solid contents of a sphere or globe, whose circumference is described by the circle *a b g c*, will be 1728 times larger than a sphere of the size of *a*.† Next, I observe another kind of animalcule (*e*) which, measuring by my eye, through a good microscope, I suppose to be a fourth of the size of the first animalcule *a*, then the size of *a* must be 64 times greater than that of *e*.‡ Now as the grain of sand represented by the circle, *a b g c* is 1728 times larger than the animalcule *a*, multiply 1728 by 64, because *e* is 64 times smaller than *a*, and we find then it would take 110,592 animalcules§ of the size of *e*, (supposing their bodies were of a spherical figure,) to make a ball as

Fig. 2.



---

* Pronounced *animalcu-le.*

† The student, by referring to solid or cubic measure in his Arithmetic, may find the manner by which this computation is made, by raising 12 to the third power or cube, the number 1728 is obtained. Thus $12 \times 12 \times 12 = 1728$; or, twelve multiplied by twelve, multiplied by twelve, equals one thousand seven hundred and twenty-eight.

‡ The solid contents is here meant; as, $4 \times 4 \times 4 = 64$.

§ Pronounced animalcu-les, *e*, in the last syllable long. The plural of animalcule in Latin, is *animalculæ*.

large as the grain of sand, *a b g c*. Lastly, I perceive third kind of animalcule, as seen at *f*, the size o which appears to be only a tenth part of the animal cule at *e*, let this number be again multiplied as befor and we find that more than one hundred millions o animalcules can be contained within the compass o a grain of sand.

"In thousand species of the insect kind,
Lost to the naked eye, so wondrous small,
Were millions joined, one grain of sand would cover all,
Yet each within its little bulk, contains
A head which drives the torrent through its veins;
Muscles to move its limbs aright; a brain
And nerves disposed for pleasure and for pain;
Eyes to distinguish; sense whereby to know
What's good or bad; is, or is not its foe."

44. Such are some of the instances of the great m nuteness with which matter is divided; and when w consider that each animalcule is a living being, fu nished with limbs and vessels to carry on the oper tions of life, we must acknowledge that God is no les great and wise in minute things, than in his vast an sublime creations.

*Atoms.**

45. The ancient Greek philosophers, who studie much into the nature of things, believed that all sub stances were composed of extremely minute part called *atoms*, which could not be divided. Sir Isaa Newton, a great modern philosopher, was of the sam opinion.

46. Some philosophers, however, because we se

* A word derived from the Greek, *a* not, and *toma* cut, meanin what cannot be divided.

44. Reflections derived from the minute works of God.
45. Opinions of the ancient philosophers respecting atoms?
46. Why have some philosophers asserted that matter is infinitel divisible?

no particle of matter so small that it may not be again divided, have asserted that matter is *infinitely divisible*, or that there are no *indivisible atoms*.

47. Late discoveries in chemistry, by ascertaining exactly the *proportions* in which substances are composed, show us that, one, two, three, or more portions of one kind of gas or element, combine with one, two, or three &c. of another kind of element, and that there is a perfect regularity in their combination. It is therefore inferred that every simple subtance is composed of atoms, or indescribable particles.

48. This discovery proves that God who formed every *atom* in creation, has them all under his control. He is, doubtless, as familiar with each individual atom in the universe, as we are with our household goods, or those ingredients which we mix together to form new compounds. The terms *molecule* or *particle* are used to denote very minute parts of matter; and, sometimes, they are used in the same sense as atoms.

Porosity.

49. Substances are more or less *porous*, that is, they have intervals or interstices between their parts. In a piece of light bread, or sponge, the pores are very conspicuous.

50. With the microscope, and even in some cases without, pores may be discovered in the human skin; these are provided by the Creator for the purpose of carrying off, by perspiration, morbid matter from the system, which would otherwise cause disease. Thus when any sudden cold checks the natural perspira-

---

47. What have late discoveries in chemistry shown?

48. What does the discovery of this regularity in the combination of substances prove?—What is meant by the terms molecule and particle?

49. What is meant by substances being porous?

50. Can we discover pores in the human skin?—For what purpose are they provided?

tion, disease follows, and the first effort of the physi is to cause the pores of the skin to perform their ac tomed offices.

51. Gold is porous; this has been proved by filli ng hollow globe of this metal with water, and submit tin it to great pressure; the outer surface of the glob becomes moist with the water which has been for ced through its pores. Mercury or quicksilver has, by pressure, been forced through a piece of dry wood and made to fall in finely divided particles. Mercury may also be squeezed through some kind of leather merely by the pressure of the hand. The fact that tight leather shoes, when long exposed to water, become soaked through, also proves that leather is porous.

Compressibility.

52. When we squeeze in the hand a piece of bread, we bring the particles of which it is composed nearer together; this is called *compression.*

53. If bodies were not porous, they would not be compressible.

54. Wood may be easily compressed. Pieces of oak or other wood plunged to a great depth in the sea, when drawn up, have been found to be compressed to a size much less than before they were submerged, and to be so heavy that they will sink in water like a stone. Even cork, which floats on the surface of water, when forced for a long time to remain to a great depth in the sea, becomes so hard and solid that it will sink. An empty bottle corked and let down into the sea, at a certain depth, will be found filled with water. The water is forced in at

---

51. Is gold porous?—How is it proved to be so?—What is said of the porosity of wood and leather?

52. What is meant by compression?

53. What renders bodies compressible?

54. How is the compressibility of wood and cork proved?

the sides of the cork, which becomes smaller by compression.

55. Water, itself, is compressible, though it was long considered not to be so.

56. It is now proved that at the depth of one thousand fathoms* water occupies one-twentieth less space than at the surface of the sea.

57. Air is exceedingly compressible. When confined, and subjected to a heavy pressure, a volume of air containing one hundred pints may be compressed into the capacity, or size of one pint.

Elasticity.

58. Elastic bodies are such as spring back when released from compression.

59. India rubber is elastic, which you can easily perceive by drawing out a small piece and observing the force with which it springs back. An ivory letter-folder may be bent, but as soon as it is released from pressure, its elasticity will force it back. A steel sword-blade, a carpenter's saw, a foot ball, and all bodies that spring back from pressure, or rebound, are elastic. Air is very elastic; this property of air we shall hereafter consider.

Density.

60. In common language, one substance is said to be more dense than another, when its particles are less separated by pores; thus heavy bread is more dense than light bread, and iron is more dense than wood.

* A fathom is a measure of six feet.

55. Is water compressible?
56. How is the compressibility of water proved?
57. Is air compressible?
58. What are elastic bodies?
59. Give examples of elastic bodies.
60. When is one substance said in common language to be more dense than another?

61. To express the same scientifically, *the gre the quantity of solid matter contained in a g space, the more dense is the substance.*

62. If we should weigh one cubic inch* of cork, another of lead, we should find the weight of the inc lead, greater than that of the cork; we thus find tha cork, within a given space, contains a less quantit solid matter than the lead, therefore we say lea more dense than cork.

63. The comparative weight or density of substa is called *specific gravity.* Thus we say that the cific gravity of lead is greater than that of cork. *W is made a standard of comparison*, because it i weighing bodies in water that their specific grav are most conveniently found. A cubic inch of co four times lighter than water, a cubic inch of marb twice as heavy as water, and a cubic inch of lead i times as heavy as water. Thus the specific gravit marble is said to be 2, that of lead 11, while tha cork would be expressed by the fraction, .250; mea that if water be regarded as 1000 in respect to wei cork is 250 or one fourth.

CHAPTER IV.

Inertia—Force—Gravitation.

We fear our young students will begin to think Nat Philosophy a dull study. Explanations of the *proper of matter* cannot be expected to be as interesting

* By a cubic inch is meant a solid substance, one inch in le one in breadth, and one in thickness.

61. How may the same fact be more scientifically expressed
62. How can it be proved that lead is more dense than cork
63. What is the comparative weight of substances calle Why is water made a standard of comparison?

stories. But the young person who would forsake the pursuit of what is useful, in order to seek what is entertaining, can never be expected to attain to eminence.

64. There is a satisfaction in feeling that we have gained useful knowledge, which much more than compensates for the labor of study. While spending time in what is merely amusing, we feel dissatisfied with ourselves. We know that we are unfaithful servants if we fail to improve the talents that God has given us.

The study of flowers, of shells, and of minerals, is more pleasing to the taste than the study of abstract qualities, which must form a part of Natural Philosophy. But as the lightest soil is not always the most productive, neither do the most entertaining and easy studies bring forth in the mind the richest fruits. But every thing is good in its kind; you must not despise other studies, while you duly estimate the value of the one you are pursuing. The tree of science has its flowers and fruits as well as its roots and trunk; Mathematics, Natural Philosophy and Chemistry may be considered as constituting the latter, while Botany and other departments of Natural History may be compared to the former.

65. The next property of matter that we shall consider is, *Inertia.*

When you see animals moving about, or remaining at rest, you infer that they *choose* to be in the one state, rather than in the other.

66. When you see an apple falling from a tree, or a stone moving through the air, or observe either of them at rest on the ground, you do not suppose that it moves or rests from any choice of its own.

67. Inert matter has, of itself, no tendency either to

---

64. Importance of seeking knowledge rather than amusement.
65. Why do animals move about, or remain at rest?
66. Does an apple or a stone move or rest from choice?
67. Has matter, of itself, any tendency to rest or motion?

rest or motion. When put in motion it continues to move until stopped by some power or force other than its own; and when at rest, it remains so until put in motion by some external force.

68. *Inertia* then means *that property of matter by which, when at rest, force is required to move it, or, when in motion, the application of force is required to stop it.*

69. Force, therefore, is necessary to put matter into motion, and to stop it when it is moving. But what force do you suppose causes the stone which is thrown upwards to fall again to the earth?

70. We will consider this. Suppose a stone is at rest on the ground; it is manifest that it would never move from that spot by any force contained within itself. You exert your strength to throw the stone upward; at first, it moves rapidly, but its motion becomes slower and slower until it ceases; a downward motion then commences, and as the stone descends, it moves faster and faster until it reaches the earth.

71. You know that the force which made the stone move upward, was the strength of your arm. Had no contrary force been exerted upon the stone it would have continued to move on through the regions of space. But as soon as it is thrown from your hand, its motion begins to lessen as if some force were exerted to keep it from rising. To understand this, you must know that there are two forces which act upon the stone, thus put in motion, and impede its progress; these are, 1st the resistance of the air, and, 2d the attractive power of the earth; the latter is called

---

68. Define Inertia.
69. For what is force necessary?
70. What takes place when a stone is thrown upward?
71. What forces impede the motion of a stone when thrown upward?

Gravitation.

72. Gravitation is a property which belongs to all bodies, and is exerted by them upon each other *with a force proportioned* to *their magnitudes.* The earth, therefore, being a body of immense magnitude, compared with the little stone which we have before supposed put in motion by the strength of your arm, continually acted upon it, gradually impeding its progress and drawing it to itself. But to us, *gravitation* is a concealed power, except, by its operation. We cannot see, feel, or hear it, but we see its effects, and therefore we know it exists. May we here be permitted, with reverence, to suggest an analogy between the Infinite Creator and his works. God, though not manifested to any of our senses, is nevertheless, constantly proving his existence by his Power, the effects of which, we see on every side.

CHAPTER V.

Cohesion, or the Power of Solid bodies to resist pressure. Principles of Philosophy applied to Architecture.

73. *Attraction* is that power in nature which tends to bring the particles of matter together: *Repulsion* tends to drive them asunder. Attraction and repulsion are antagonist, or opposing forces. The great agent of repulsion is *heat*, which is powerful in separating the particles of bodies.

74. There are several kinds of attraction. Those

72. What do you know of gravitation?
73. Define attraction and repulsion.
74. What holds solid bodies together?—What can destroy cohesive attraction?

which chiefly concern the beginner in Natural Philosophy, are *Cohesion* and *Gravitation*. The attraction of Cohesion takes place between particles that are near together. All solid bodies are held together by it. When a log of wood is burnt, its cohesion is destroyed by heat. The particles which were before held together are driven apart; some go off in vapor, and some remain in the form of ashes.

75. If cohesive attraction should cease to keep together the solids out of which the furniture of a room is made, we should see tables, chairs, looking-glasses, and iron stoves, all falling to pieces, and forming masses as loose as piles of ashes or sand.

The attraction of gravitation acts upon a grander scale; it is this which holds together the solar system, keeping suns and planets, with their moons, in their several stations. We shall now proceed to consider

The Attraction of Cohesion.

76. The strength of solid bodies may be tried in various ways, by pulling, pressure, straining, &c.

77. The resistance to be overcome is that of *Cohesion.*

78. Some substances possess this property in a much greater degree than others.

79. Iron and gold are very cohesive. Iron can be drawn out into fine wire; and gold may be beaten in leaves many times thinner than any paper.

80. It has been proved by experiments, that an iron

---

75. What would be the effect upon solid bodies if cohesive attraction should cease?—How does the attraction of gravitation differ from that of cohesion?

76. How may the strength of solid bodies be tried?

77. What is the resistance to be overcome?

78. Do all bodies possess the property of cohesion in the same degree?

79. What is said of the cohesion of iron and gold?

80. How is it proved that iron is more cohesive than lead?—Why is iron used where great strength is necessary?

rod an inch square, will bear a weight of 76,400 pounds, while a rod of lead, of equal size, will only bear 430 pounds. The particles of lead, then, are much less influenced by cohesive attraction than those of iron. This latter substance is therefore used where great strength is necessary, as in carriages, machinery, buildings, chains, &c. You could easily break with your hand a leaden plummit, while a piece of iron of the same dimensions would resist all your force.

81. Boxwood is a firm and compact material, and very cohesive. A square inch of boxwood will bear 20,000 pounds weight, while a square inch of mahogany will bear only 8,000 pounds.

82. An experiment being made with the muscle which bends the thumb, taken from a man after death, it was found to bear a weight of twenty-six pounds before it broke. In a living man this muscle will bear a much greater weight.

83. The strength of bodies depends on their size, figure and situation, as well as the cohesion of their particles.

84. Of bodies, in other respects equal, the largest one is proportionably the weakest, or offers the least resistance.

85. Thus, if two masses of rock project from a precipice, the larger mass, *d*, would fall with the addition of a less weight than the smaller mass, *b*.

---

81. Which is most cohesive, boxwood or mahogany?

82. What is the strength of the muscle in a man's thumb?

83. On what, besides cohesion, does the strength of bodies depend?

84. Does the size of a body, in other respects equal to another, give it an advantage in strength?

85. Give an example.

Fig. 3.

86. There are two re sons for this; first, in t larger mass, each partic at the point of cohesi at the precipice, *c*, has support twice the weig of the particles in t smaller mass at *b*. In t second place, any weig at the end of the larg mass, would act with double advantage,* break it off. Even i own weight is sufficient to precipitate a rock whi projects to any extent horizontally, from the side of mountain.

87. A plank, supported at both ends, will break wi a weight, less, in proportion to the length of the pla between the supports.

88. Hills and mountains vary in appearance, accor ing to the strength or cohesion of the substances which they are formed. Granite, the most hard a compact of all the rocks, presents lofty and projecti precipices, while the softer rocks show more round surfaces, and hills of sand exhibit a regular outline.

89. The cohesion of rocks, is considerably weake ing, through the influence of rains, winds, and frost

* The pupil will learn the cause of this double advantage, wh he understands the increased power of a long lever over a sh one.

86. Why would not the larger mass of rock be able to bea greater weight than the smaller one?

87. When supported at the ends, which will bear the grea weight, a long or short plank?

88. What causes the various appearances of hills and mo tains?

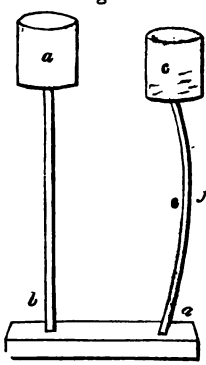
89. What is constantly weakening the cohesion of rocks?

and the aspect of a country changes, by the falling of large masses from higher to lower stations; and an accumulation of particles which are washed from the hills into the valleys, by the water which is constantly flowing.

90. It is important to the strength of any substance, that the force acting upon it, shall operate as uniformly as possible through the whole mass.

91. Let there be two pillars of the same diameter, the one straight, and the other somewhat bent, the straight pillar would sustain, without breaking, a greater pressure than the bent one. Thus the weight, *a*, is equally sustained by all the parts of the pillar, *b*; while the weight, *c*, bears chiefly upon the particles on the concave side, *e*, of the pillar, *a*. The parts at *e*, are, therefore, in danger of being crushed, while those on the opposite side, at *f*, are exposed to be torn asunder.

Fig. 4.



92. Try the experiment with a slender rod, and on bending it, you will find the separation of the particles will begin on the rounding or convex side, while the particles on the concave side will be pressed closer by the strain upon them.

93. Long pillars, or supports, are more easily bent, than short ones of the same diameter.

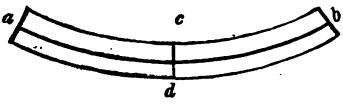
94. The case of a weight bearing downwards upon a pillar, is to be referred to *longitudinal pressure.*

---

90. What is said of a force acting uniformly on any structure?
91. Explain the figure.
92. When you break a slender rod, when do the particles begin to separate?
93. Which are more easily bent, long or short pillars?
94. Give an example of longitudinal pressure.

95. *Transverse pressure.* A horizontal or tran verse beam, supported at its two extremities, *a* and *b*, liable, under pressure, to bend in the middle; the pa

Fig. 5.



ticles on the upper sid *c*, being compresse while those on the lo er side, *d*, are stretch out. A very sm crack in the lower si of a beam or plank th situated, will often cause the whole to give way.

Principles of Philosophy adapted to Architecture-Domes and Arches.

96. Builders have contrived various methods f strengthening the frames of edifices. Thus, in the ra ers for supporting the roof of a house, many bean extending in different directions are joined togethe and set bracing, so as to sustain each other.

The young student should take all proper opportun ties to examine the operations of carpenters, ship-buil ers, and other mechanics, as they are practical illustr tions of mathematical and philosophical principles.

97. Arches are used for bridges and other structure where great pressure is to be resisted.

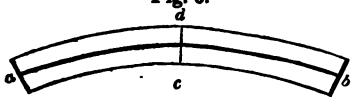
98. The supports of arches are called *abutments.*

99. *a b* represents an arch; any pressure on the u per side, *d*, will not, as in the last figure, tend to sep

---

95. Give an example of transverse pressure.
96. Why are there many beams extending in different directio in the frame of buildings?
97. Why are arches used in buildings?
98. What are abutments?
99. Describe the figure?

Fig. 6.



rate the particles on the lower side, *c*, but will compress them in nearly the same degree as the parts in the upper side of the plank, are compressed. The whole arch resists pressure, much in the same manner as a straight pillar bears a weight.

100. The great domes of churches, such as the celebrated edifices of St. Peter's, at Rome, and St. Paul's, in London, are able, by their arched forms, to resist the great horizontal pressure to which they are exposed by the weight of the roof.

Fig. 7.

101. The figure represents a bridge over the river Taaf, in Wales. It is remarkable for the length of its arch. Its span, or the greatest distance from end to end, being 140 feet. Its height is 34 feet.

---

100. How are the domes of churches able to support the great horizontal pressure to which they are subjected?

101. For what is the bridge of Taaf remarkable?

102. The middle stone of an arch is called *stone.*

103. There is danger that the sides of an ar press with too great a weight upon the key-st force it up. In the bridge of Taaf, this accide took place.

104. It was remedied by the ingenious exp lessening the pressure by means of removing the stone work in the sides, and forming circu ties, called *tunnels.**

105. The *Gothic Arch* is pointed; the chie is upon the summit or key-stone. It is not t used as much for bridges, as for windows and churches and other edifices, in situations wh arch has not to sustain heavy pressure.

* Three of these tunnels appear in the figure on each are circular, and distinguished by a dark shade.

102. What is the key-stone?
103. What accident took place in the Taaf bridge?
104. How was this accident remedied?
105. Describe the Gothic arch.—What is said respect formity in the style of architecture?

Fig. 8.

The figure shows a Gothic arch as seen in the doors of churches and other buildings. The doors, windows and ornaments of a building should present a similar style of architecture. For want of attention to this rule, which is founded in good taste and a sense of propriety, we often see various kinds of architecture crowded together in the same building. This is much like making one side of a garment in a dif-

t form from the other side. Travellers in America often criticised upon this mixture of different ; of architecture, which is probably more common g us than in the older countries of Europe.

). Various examples might be given of the strength ı results from the arched or domed form. If a glass globe, filled with water and closely corked, ; down into the sea to a great depth, it will resist ressure of the water above it; while a square ; of much greater thickness, will be crushed by ressure. An egg-shell will break much more , if struck with a knife or spoon upon one side, if the blow fall upon the part which is most con- r arched.

Give some examples to show that the arch or dome form is ive to strength.

107. The arched form of the human skull, shows th wisdom of the Creator in protecting the brain by covering of great strength, and at the same time o little weight.

108. To determine, for particular cases, the best for of beams and joists, arches, domes, &c., is the busines of strict calculation, and belongs therefore to mathe matics, or to the *science of measures*.

109. "It was a beautiful problem which Mr. Smea ton, the English engineer, solved in the construction o the far-famed Eddystone light-house, in England. H had to determine the form and construction of a buil ing, which should stand firm on a sunken rock, in th channel of a swift ocean tide, and exposed to the fur of tempests from every quarter. Only the man wh has, himself, been driven before the irresistible storm in the darkness of night, and in the midst of danger and whose eyes have watched the steady ray from th light-house which saved him, can appreciate fully th importance of the structures which bring such usefu results."*

* Arnott.

107. What is said of the structure of the human skull?

108. Does any part of the structure of buildings belong to m thematical calculations?

109. Construction of the Eddystone light-house.

110. Eddystone light-house is erected on the rocks

Fig. 9.

of that name, which lie in the English channel about 14 miles from Plymouth. These rocks were called the Eddystone probably from the whirl or eddy occasioned by the waters striking against them. They formed a dangerous obstacle to navigation; and many a gallant ship with its crew, while nearing the port, in sight of their native shores, has been sunk upon these hidden breakers. It was desirable that this spot should be pointed out by a warning light. But the circumstance that rendered these rocks so formidable to the mariner, made it also difficult to erect a light-house upon them. Two light-houses had been erected, one of which had been burned, and the other swept away

110. Architectural strength of the Eddystone light-house.

by the winds and floods, when Mr. Smeaton in 1759 erected the one that still stands, a certain and safe beacon to the mariner. It is a round building, (as may be seen in the figure,) built of hammered stones, forming a solid column, gradually decreasing in circumference from the base to a certain height, like the trunk of an oak, from which emblem of strength and solidity, the architect, it is supposed, took his idea of this structure.

CHAPTER VI.

Attraction of Gravitation.

111. By *gravity*, or *gravitation*, is meant that property by which large masses are attracted towards each other.

Chemical attraction causes the particles of bodies of different kinds to unite together, forming a new compound. Thus, the common liquid hartshorn, or *ammonia*, unites with sweet oil, forming a soap-like mixture called *volatile liniment*. Here each particle of ammonia attracts each particle of oil, the nature of both is changed, and a new substance formed, which is neither oil nor ammonia.

112. Gravity does not unite substances so as to alter their nature; it may bring them close together, but does not, like chemical attraction, incorporate them into one body. If an apple is separated from the tree, the at-

111. What is meant by gravitation?—What is the effect of chemical attraction?

112. Does gravity, like chemical attraction, alter the nature of substances?

traction of gravitation causes it to fall towards the surface of the earth; but gravitation does not cause it to mix with the earth. Chemical attraction does not begin to act until the surfaces of bodies are in contact.

113. The earth's attraction causes heavy bodies, which are not firmly supported, to fall towards it. If the moon were so near as to come within the sphere of the earth's attraction, unbalanced by any opposite force, it would fall upon it as the ball which is thrown upwards falls to the earth.

114. But attraction is not confined to the earth alone. The sun and the planets mutually attract each other; and, by a contrivance worthy of the Almighty, these vast bodies are supported, though resting upon nothing, moving in, and enlightening their vast orbits,

"Forever singing as they shine,
The hand that made us is divine."

115. Sir Isaac Newton is the first who is known to have thought and reasoned upon the subject of gravitation.

116. From the earliest periods, mankind had seen things fall to the earth, but it appeared "*so natural*," that they did not think of inquiring into the cause.

117. Every natural operation has a cause, but we, in general, appear more interested in uncommon appearances than in those which we every day behold. Should you see the stones and other objects which now rest on the earth, begin, of themselves, to rise upwards, you would go to wiser people than yourselves to inquire what made them do so. These wise people would call it a *phenomenon*, and set about searching for a cause.

---

113. In what case would the moon fall upon the earth?
114. Does attraction exist among the heavenly bodies?
115. Who first thought upon gravitation?
116. Why had not the cause of gravitation been thought of before Newton?
117. Are common operations produced without a cause any more than uncommon ones?

118. That bodies should, of themselves, and wit any apparent force, fall towards the earth, is, in res as wonderful as if they should rise from the earth; custom has rendered the former so familiar that n people would be surprised if one should ask them cause.

119. It is common things that we should, chiefly deavor to comprehend. The greatest discoveries inventions have been the result of attention to th into which, on account of their supposed insignifica most men have never thought of inquiring.

120. When Newton had satisfied himself tha earth possessed a power of attraction, he extende views to other worlds; and the grand, simple, beautiful principle of *universal* attraction was rev to his mind.

121. He proved that by the force of the sun's a tion, combined with another force, called the *proj force*, the earth and the other planets in the solar tem are kept moving around the sun; and tha moon, by the earth's attraction, combined with a jectile force, is kept moving around the earth.

122. The smaller bodies, in their turn, attrac larger, but their attraction is less, in proportion as quantity of matter is less. The stone, as it fall wards the earth, attracts the earth towards it, but slightly to be perceived by our senses.

123. The moon attracts the earth so much as to

---

118. Would it have been more wonderful if bodies had repelled from the earth's surface, than it is that they are att to it?

119. Should we disregard common things?

120. Did Newton confine his views of attraction to the ear

121. How did he explain the motion of the planets round th and of the moon round the earth?

122. Do smaller bodies attract larger?

123. What changes are produced on the surface of the ea the moon's attraction?

important changes upon its surface, such as tides, or the ebbings and flowings of the sea, twice every day.

124. As the moon is a smaller body than the earth, its attraction is less, and therefore it moves round the earth. Were the moon larger than the earth, the earth would be its satellite or attendant, instead of being the primary body, as it now is.

125. *Weight*, or pressure, is the effect of gravitation.

126. The force of gravity is greatest at the earth's surface, and becomes less as the distance from the surface increases. A body, therefore, weighs less upon a high mountain, or in deep mines, than at the level surface of the earth.

CHAPTER VII.

Centre of Gravity.

127. We will suppose a basket of apples to be standing on the floor; turn it partly upon one side, it will still stand, turn it a little farther and it will upset. As long as a *certain point, called the centre of gravity*, is supported, the basket is not turned over, but, as soon as this point is raised, it falls.

128. The centre of gravity in the basket would be in a line through the centre of the basket, this line is called the *line of direction.*

---

124. In what case would the earth move around the moon?

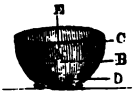
125. What causes Weight?

126. Why does a body upon a high mountain, or in a mine, weigh less than at the surface of the earth?

127. How far can a basket of apples be turned on one side, without upsetting?

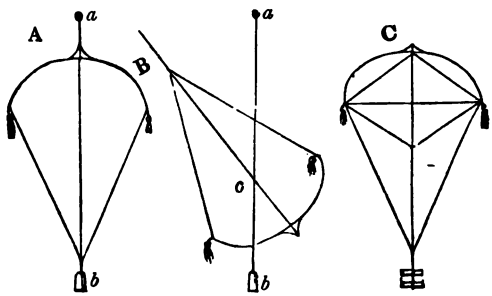
128. What is meant by the line of direction?

Fig. 10.



129. Suppose the figure to be a solid body, with a hemispherical base, and that A is the centre of gravity: if force be applied vertically at E, no motion would be produced; but if force be applied at B, directly opposite the centre of gravity, it would be destroyed by the inertia of the mass, or if great enough to overcome this, would move the body before it. If a small degree of force were applied at C or D, or at any other point above, or below B, it would cause the body to rock or vibrate, and a greater degree of force would overturn it.

Fig. 11.



In substances having a regular figure and uniform density, the centre of gravity is easily found; otherwise, it is necessary to make use of the *plumb-line.** When a boy makes a kite, he must find out the centre of gravity, or the point on which to balance it, when he attempts to fly it. The kite is irregular in its form, and in order to find its centre of gravity, it is first suspended as at A; from the nail *a*, on which the kite

* So called from the Latin, *plum-bum*, lead.

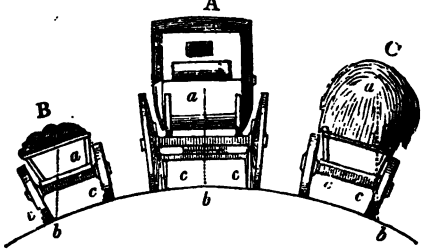
129. Explain the figure.—How is the centre of gravity found, when substances have not a regular figure?

hangs is suspended a cord, with a piece of lead, *b*, fastened to the end, this is the *plumb-line*, or plummet-line as it is sometimes called, and it will always, when freely suspended, hang in an exact perpendicular. The direction of the plumb-line is now marked on the kite, which is then hung in another position, as at B. The plumb-line is again suspended over the kite, and the point *c*, where this line crosses the line before marked, is the centre of gravity of the kite. C represents the kite after it is furnished.

130. Carriages may lean considerably to one side without turning over; but this accident will always happen when the inclination is so great as to raise the centre of gravity.

131. Suppose there are, upon a certain highway, level in the middle but sloping towards the sides, a coach and two carts. The coach A, stands on a level,

Fig. 12.



the cart B, which is loaded with stones, and the cart C which is loaded with hay, stand where the ground is sloping: *c c* represents the base of each vehicle, *a* the centre of gravity, and *a b* the *lins of direction.*

132. The coach stands firm because the centre of

---

130. How far may a carriage lean to one side without turning over?

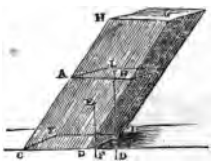
131. What does the figure represent?

132. Why does the coach stand firm?

gravity or of pressure is well supported, as will be seen by the line of direction, *a b*, which is in the middle of the base.

133. The stone cart inclines much to one side, but as the line of direction is still within the base, it will be supported; but the hay cart will be upset, because the line of direction is beyond the base. The centre of pressure, *a*, in the load of hay, is higher than in the load of stone. A load which is heaped very high is said to be *top-heavy*.

Fig. 13.



134. Suppose a block of wood, A B C D, standing upon one end, and so long as the line of direction falls within the base, the body will be supported; but, by placing on the block of wood, another block, A B G H, the centre of gravity of the whole pile is now at L, and, therefore, as the line of direction, L D, falls without the base D, the centre of gravity is not supported, and the whole will fall.

135. You may now perceive the danger of rising in a carriage, or in a boat, when it inclines to one side; as in doing this, the centre of gravity is elevated. Stages with baggage piled on the top, are more exposed to accidents than when the load is nearer the wheels.

136. A quadruped is better supported by his feet than a man, because the points of support are more numerous and more distant. A person who should attempt to walk with his feet close together, would find it difficult to keep himself from falling.

---

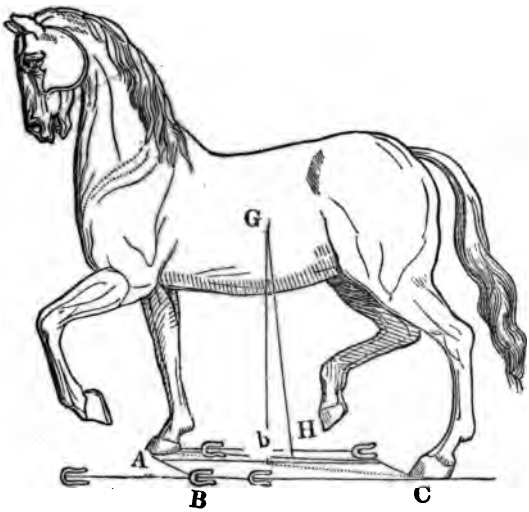
133. Why is not the stone cart as likely to upset, as the hay cart, when standing on ground equally sloping?

134. Explain the figure.

135. Why is it dangerous to rise in a carriage or boat when it inclines to one side?

136. Why is a quadruped better supported by his feet than a man?

Fig. 14.



137. Let G represent the *centre of gravity* in a horse, A C the base or extremity of the supports, and G H the *line of direction.* When the other feet rest at B and C, the centre of gravity is still the same, but the line of direction is G, b.

138. It is not necessary that the base should be entirely solid, if the points of support are firm, as may be seen in a table supported by its legs.

139. If a large table were made with but one leg in the centre, it would not stand firm, but let the pillar on

---

137. Explain the figure.

138. Is it necessary that the supporting base should be entirely solid?

139. What advantage has a pillar terminating in a tripod, in the support of a table, over one leg in the centre?

which the table rests, terminate in a tripod,* a
have the same stability as if it had three ei
making a base as wide as the extreme poir
feet of the tripod.

Fig. 15.

140. At Y
in Englan
monument
celebrated
son. It i
column of s
mounted
lossal figu
an immen
could not
sustained
very broad
to lessen
increase t
of the str
is suppo
walls, for
the interic
cious a
which is
by a fligh
or stairs.

* A tripod originally signified a seat with three le
based on three feet is here meant.

140. How is Nelson's monument supported?

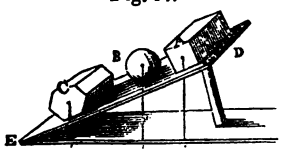
Fig. 16.

141. When an oval body, A, resting on a level surface, B C, is moved to either side, the centre of gravity must rise, as in the pendulum of a clock; it will then descend, and thus the original force which set it in motion, (in other words, the projectile force,) and the force of gravity, will cause a vibration or rocking; the motion of a child's rocking-horse, and a cradle, are examples of this.

142. The rocking stones or *tors* as they are called in Great Britain are remarkable examples of motion in a very large mass produced by moving the centre of gravity. These rocking stones are huge masses of rock, which, by earthquakes, or some great force, have been torn from the mountains above, and remain resting with a rounded base on a flat surface of rock. The centre of gravity is here supported on a point, and a child may cause a mass to vibrate which many yoke of oxen could not draw.

143. In all spherical bodies, the base is but a point, so that the smallest force, is sufficient to remove the line of direction beyond the base. Thus a barrel will easily roll, while a square box of equal weight, must be pushed, or drawn along, and with a much greater expense of force.

Fig. 17.



Thus you perceive that A, by its line of direction, will slide down the inclined plane, DE, while B and C will roll down the same.

141. What is the effect of moving an oval body resting on its centre of gravity?

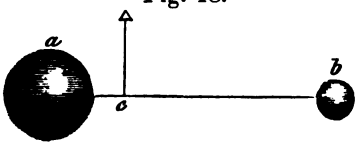
142. What is the reason that the rocking stones are so easily put in motion?

143. Why are spherical bodies easily moved?

144. The easy motion of a cradle and rocking has been mentioned as an example of the vibration ed by gravity. A slight projectile force is necess raise the centre of gravity, the earth's attraction it down, the impulse from velocity again carries and attraction again causes it to descend; this tion will continue until the original force with the motion began, is exhausted by friction and gi A swing operates in the same way; the vibrati the pendulum of a clock are also caused by grav

145. When two bodies of equal weight are co ed by a rod, the centre of gravity will be in the r of the rod, and a string fastened to this point wil the whole in equilibrium.

Fig. 18.



146. But if t dies are of u weight, the ce gravity is near greater weight is, if *a* be a of three pound *b*, a weight of one pound, the two will be balan suspended at a point in the rod, *c*, three times to the centre of the large weight, than to that small one.

A person carrying a burden on his back, lea ward in order to bring the centre of gravity be the feet, or supporters. While, for the same rea

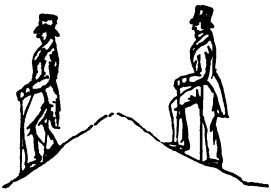
144. How does gravity continue motion in a cradle, r horse; swings and pendulums?

145. Where is the centre of gravity when two bodies o weight are connected by a rod?

146. If the bodies are of unequal weight, where is the c gravity?—Why does a person carrying a burden on his ba forward?—Suppose the burden to be carried in the arms, o head?—What are the natural positions in ascending and d ing a hill, or staircase?

Fig. 19.

Fig. 20.



burden in the arms causes one to lean backwards, or if it be on the head, to stand upright. In ascending a hill or staircase, a person leans forward, in descending, he leans backward.

CHAPTER VIII.

Power.

147. The word *power*, is one of great importance in language. It signifies that, without which nothing would ever have existed.

148. If power were not constantly exerted, every regular action in the universe would cease, and disorder and decay would take the place of the harmony and beauty which nature now exhibits.

149. God himself, is the great fountain of power. That his power is infinite or boundless, we may well believe, when "we consider the heavens which he has made, and the wonders which he does on the earth." Let us remember, then, that as all power is derived from God, he can, at his pleasure, take away or change the nature of his gifts.

---

147. Importance of power.
148. What if power were not constantly exerted?
149. From whence is power derived?

150. There are, in nature, two kinds of power, *mental* and *physical.*

151. Man, in the efforts of his mind, is said to exercise mental power, and in the efforts of body, physical power.

152. The mind, or spirit of man, is placed within a body, made of the same material as the earth he treads on. The body is moved and governed by the mind, and when the mind is gone from it, as at death, it is as incapable of action as a clod of earth. Thus we see that in man, physical power, seems, in a degree, to depend on mental power.

153. There are some acts which the mind seems to perform independently of the body, these we call *mental.* When we lie in the silence of the night, and think of past events, or imagine the future; when the soul is filled with thoughts of the goodness of God and when we pray to Him, our body may be inactive and appear to have as little to do with the operation of the spirit, as if they were not connected.

154. When we walk or run,—when we use our hands, eyes, or any of the members of the body, we exercise physical power or perform *physical operations.*

155. But though the body seems, in many cases, to act independently, yet it is acted upon, and made to act only by the power of the mind.

156. Persons of great mental power, have often little physical strength. The man who excels in wis-

---

150. What two kinds of power are there in nature?

151. What kind of power can man exercise?

152. Does physical power in man seem in any degree connected with mental power?

153. What do we call those acts which the mind alone performs?—Inactivity of the body in some mental operations.

154. When do we exercise physical power?

155. What causes the body to act?

156. Great mental power often accompanied with little physical strength.—Relations between physical and mental power.

dom, does not so often possess uncommon bodily or physical ability, as those of less powerful minds. But though the mind is the nobler part of man, the body should not be neglected; because a sound mind depends greatly upon a sound body. We cannot think so clearly in bodily pain or weakness, as when the body is in a healthy state. God has established sympathetic relations between our physical and mental powers, which we should be careful to study.

157. Beasts possess physical power, and often in a much greater degree than man. The elephant is stronger, the horse can run faster, the dog can smell more acutely, and the cat can hear better than man.

158. Thus we see, that in respect to physical power, we have nothing to boast of, over the brute creation; it is in our superior mental power, that we have the pre-eminence, and by it we are enabled to exercise that dominion over the inferior animals that God has given us.

Animals, however, possess some degree of mental power. A horse differs wholly from an inert machine. When a horse stops and refuses to move, his driver considers him *wilful*, and applies the whip in order to alter or subdue his will, and make him wish to move, rather than suffer the pain of the whip. When a machine stops, and resists all efforts to move it, no one supposes this to be the effect of any wilfulness on the part of the machine, but we examine to find what portion of the machinery may be broken or out of order.

159. Machines, therefore, by the first law of matter, (its inertia, or inability to move when at rest, or to rest when moving,) possess no power to move themselves.

---

157. Do some animals possess greater physical power than man?

158. In what consists the pre-eminence of man over the brute? Do animals possess any mental power?

Can you explain the difference between the operations of a horse and of a machine?

159. Can there be a self-moving machine?

There has never yet been invented, a self-moving machine; though many, ignorant of the laws of matter and motion, have foolishly imagined such a thing might be made.

160. The Great Author and source of power, withholds from us the secret of *perpetual motion*, though He is, himself, constantly exhibiting it to us in the motion of the heavenly bodies and planetary spheres.

161. The physical powers of inanimate nature, as water, wind and steam, are applied to the moving of various kinds of machinery; and mechanical operations, and labor of various kinds, are carried on by the physical strength and power of men and animals, greatly aided, in some instances, by the application of certain principles called *Mechanical Powers*.

CHAPTER IX.

Motion—Momentum—Motion Downwards—Motion Upwards.

162. Motion, in any substance, can neither be produced nor stopped, without the application of power; that is, a mass of matter cannot move itself, nor put itself at rest.

163. *Inertia* or *inactivity* is a term used to express the want of power in matter to change its state.

164. It requires as much power to stop a carriage in

160. Reflections on perpetual motion.

161. What powers are usually applied to move machinery?—How are mechanical operations otherwise carried on?

162. How is motion produced or stopped?

163. What is the term inertia used to express?

164. Does it require power to stop a vehicle when in motion?—Why does the sudden stopping of a horse in motion render the

motion, as to start it. A steam-boat requires more power to set it in motion, than to continue the movement; and when in motion, it will not stop the instant the engine ceases to act upon it. If, when a person is riding on horseback, the horse suddenly stop, the rider is liable to be thrown forward; while the sudden starting forward of a horse, may throw the rider backward. The former case proves the inertia of motion, the latter of rest. A skater, moving with swiftness, suddenly sees directly before him, a dangerous break in the ice, but the power of the will is not sufficient, instantly, to overcome the inertia of motion, and the body moves forward into the opening chasm.

Fig. 21.

165. The *inertia of a body is in the proportion to its quantity of matter, that is, to its weight.*

166. The degree of power needed to set a body in motion, or to stop its motion, depends on its inertia or resistance.

167. *Force*, signifies that power which puts a body in motion; thus we say the *force of gravity* causes bodies to fall to the earth, the *force of water* moves a mill, &c. Force and power in their general signification, mean the same thing.

168. *Velocity* is the rate or *speed* at which a body moves.

---

rider liable to be thrown forward?—Why is the skater not able to stop his motion instantly?

165. To what is inertia proportioned?

166. On what depends the degree of power necessary to set a body in motion?

167. What is the power which puts a body in motion called?

168. What is velocity?

169. *Momentum* is the force with which a body in motion moves. A large body, moving swiftly, has great momentum, which is proved by its overcoming great resistance. If a child, in running swiftly, come in contact with a man, the shock will be slight; while a heavy person moving with the same velocity, would have a momentum sufficient to overthrow the man.

170. *Momentum depends on weight and velocity.*

Examples.

1st. If a body A, be equal to the body B, but A, has twice the velocity of B,—A has twice the momentum or quantity of motion as B.

2d. If A, have twice the weight of B, and move with twice its velocity, A will have four times the momentum of B; for it will have twice the momentum of B, from its weight, and twice the momentum of B, from its velocity.

3d. If A and B are equal in weight, and move with equal velocity, their momentums* are equal.

4th. A ball weighing two pounds, and moving at the rate of five hundred feet in a second, will have as much momentum, or produce as much effect, as a ball weighing ten pounds, and moving at the rate of one hundred feet in a second; for, as 500 feet, multiplied by 2, is 1000, so 100 feet, multiplied by 10, is 1,000.

* The plural of momentum, according to the Latin termination, is *momenta*, but we prefer giving the English termination, as being more familiar to the pupil.

169. What is momentum?

170. On what does momentum depend?—Example 1st.—Example 2d.—Example 3d.—Example 4th.

Fig. 22.

171. Before the discovery of gunpowder, the implements of war were very cumbrous and heavy. Among them, was the battering-ram, used for beating down fortifications and walls of cities. The Roman Emperor, Titus Vespasian, made use of such an apparatus in destroying the walls of Jerusalem, about seventy years after our Saviour's time. But cannon balls are found to be much more powerful in their effects than the ancient battering-ram. Suppose the battering-ram represented in the cut, to weigh one hundred thousand pounds, and to be moved by the soldiers running through twenty feet in a second, we should then estimate the moving force at two millions. A cannon ball weighing but thirty-two pounds, and moving sixty-two thousand five hundred feet in a second, would possess an equal force, since the velocity 62,500, multiplied by the weight 32, would give a momentum of 2,000,000.

171. What comparison is made between the momentums of the ancient battering-rams and cannon balls?

Measure of Velocity.

172. *Space and time* constitute the *measure of velocity*. Steam-boats and rail-road cars which move at the rate of twelve and even *thirty miles* in an *hour*, are said to move with great velocity. Here the proportion of space, or number of miles *passed* through in a given time, that is, one hour, is considered great, when compared with the mode of travelling with horses, in which the velocity is not usually greater than five or six miles an hour.

173. The velocity of motion may be estimated by the *time* employed in moving over a certain *space*, or by the space moved over in a certain time. *The greater the space moved over in a given time, the greater the velocity.*

174. If a body in motion describe *equal space in equal successive parts of time*, it is said to move with *uniform motion*. When a horse travels as far the second hour as the first, his velocity during that time is *uniform*.

175. In calculations upon uniform motion, there are three important rules to be considered.

1st. To determine the degree of velocity, the *space must be divided by the time.*

Example.

If a man travel thirty miles in six hours, at what rate or with what velocity does he move? Answer—divide 30 by 6, the quotient is 5. He therefore travels at the rate of five miles an hour.

176. 2d. The *time* equals the *space divided* by the *velocity.*

---

172. What constitute the measure of velocity?
173. How may velocity be estimated?
174. When is a body said to be in uniform motion?
175. What is the first rule to be considered, in calculations upon uniform motion?—Example.
176. What is the second rule?—Example.

Example.

If a man is to go thirty miles, and travels at the rate of five miles an hour, how long a time will he require for the journey?

Ans. Let the space, 30 miles, be divided by the velocity, 5, and the quotient is 6. He will therefore perform the journey in six hours.

177. 3d. The *space* equals the product of the *time* multiplied *into the velocity.*

Example.

If a journey be performed in six hours, at the rate of five miles an hour, what is the space passed over?

Ans. Multiply the time 6, by the velocity 5, and the product is the space, viz. 30 miles.

Accelerated or Downward Motion.

178. Bodies falling to the earth by the power of gravitation, have their motion continually quickened as they descend. This is called *accelerated motion.*

179. If you put two bits of cork upon the surface of a basin of water, you will see them moving towards each other; at first slowly, but their motion increases until they rush together with great velocity. Thus the earth's gravitation continually acting upon a falling body quickens its motion at every moment.

180. From many observations and experiments, it has been proved that a body, falling to the earth, descends 16 feet the first second of time; three times 16

177. What is the third rule?—Example.

178. What is accelerated motion?

179. Example of accelerated motion.

180. How many feet does a body fall toward the earth in the first second?—How many in the second second?—How many in the third, &c.?

feet or forty-eight feet in the next second, five t
16 feet or 80 feet in the third second; seven tim
feet or 112 feet in the fourth second, &c. Her
series of *odd* numbers 1, 3, 5, 7, 9, 11, 13, &c. are
for multiplying 16, the number of feet which the
descends the first second of its fall.

181. *The spaces passed through by falling b
are as the squares of the times in which they are
ing.*

182. Suppose that a stone thrown from a high t
reaches the ground in four seconds, what is the h
of the tower; or, in other words, through what s
has the stone fallen?

Ans. The square* of the time, 4 seconds, is 16.
tiply 16, the square of the time, by 16, the numb
feet passed through the first second, and the prod
256 feet, which is the height of the tower.

183. *Gravity attracts light and heavy b
equally.*

Were it not for the resistance of the air, a fe
and a dollar, if dropped from the same height, w
fall to the ground at the same instant.

184. Let the experiment be made in the open air
the feather supported by the air, and moved by e
current, will float about, while the dollar will forc
way to the ground, apparently without resistance

185. By means of an instrument called the air-p
air may be pumped out from a tall glass vessel, c

* The square of any number is that number multiplied by
thus the square of two is four, of 4 is 16, of 5 25, &c.

181. How do you measure the spaces passed through by f
bodies?

182. Give an example.

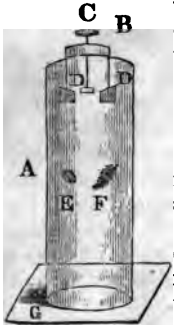
183. Why does not a feather fall to the ground as soon
dollar?

184. What takes place when the feather and dollar are dr
from the same height at the same instant in the open air?

185. If in an air-pump, which will fall soonest, the feather
dollar?—Explain the figure.

a receiver, and the dollar and feather being suffered to fall from the top of the vessel, both will descend at the same instant. The feather meeting with no resistance from the air, and equally attracted by the earth with the piece of silver, moves downwards with equal force. A, represents the glass receiver of the air-pump; B, a brass cover, through which passes a wire C, this wire on being moved upsets the little shelves, D, D, on which are placed the dollar E, and feather, F, and both strike the plate G, at the same instant.

Fig. 23.



186. When we say the feather is equally attracted with the dollar, we mean, that each particle of matter in the former, is attracted as much as each particle of matter in the latter. This is called *absolute gravity*, or that by which bodies descend freely and perpendicularly, in a vacuum, or non-resisting medium.

187. *Relative Gravity* is that by which a body descends, when the absolute gravity is constantly counteracted by a uniform, but inferior force, such as in the descent of bodies down inclined planes, or in resisting mediums, such as air, water and the like.

Motion Upwards.

188. If to a spoonful of oil in the bottom of a tumbler you add a portion of water, the oil will not remain at the bottom, but will instantly rise and float on the water. This is because oil is lighter than water. But though, in common language, we say oil rises above

186. What do we mean when we say that the feather is equally attracted with the dollar?—What is absolute gravity?

187. What is relative gravity?

188. Why does oil, in a tumbler, when water is poured upon it, rise to the top?

the water, it is, in reality, the force of the water pressing downwards which urges the oil upwards.

189. If oil were lighter than air it would not remain on the surface of the water in the tumbler, but would be pushed upward by the air getting below it, and float off like a vapor.

190. Smoke consists of the vapor of wood made lighter by being expanded by heat, and carrying with it particles of soot, coal, &c. It continues to rise until it reaches a region of air which is of its own density.

191. Steam, which is the vapor of water, and made very light and expansive by heat, will rise in the same manner. The air is constantly becoming lighter as we ascend from the surface of the earth, therefore all ascending bodies do, at length, meet with regions of air so light that they can no longer be buoyed up, and they descend again to the earth.

Retarded or Upward Motion.

192. Bodies thrown upwards are *retarded* in their motion in the same proportion as the motion of falling bodies is accelerated.

193. Try the experiment of throwing a pebble upwards with great force. At first, it will move so quickly that you can scarcely distinguish its form, but you will soon see its velocity lessen, until, after remaining an instant stationary, it begins to descend. At first it moves slowly, but every instant receiving a new impulse from gravitation, it comes downward with a speed accelerated in the same degree as the upward motion was retarded.

189. If oil were lighter than air, would it remain in the tumbler at all?

190. What does smoke consist of?

191. What is steam?—Is the air lighter or heavier as we ascend from the earth?

192. What is the effect of gravitation on bodies thrown upwards?

193. Can you give an example?

194. These effects are wonderful. An unknown force in the earth, which we call gravitation, though we do not even know of what it consists, is yet able to influence bodies which are far distant from its surface, and draw them towards it.

Some philosophers have asserted that we might as reasonably suppose there is some force above the earth which repels or pushes down ascending bodies, as that the earth attracts them. They have imagined that there might be currents of air, which they call *ether*, that exert this force. But we find attraction operating between masses where there can be no force exerted; and we therefore rest in the belief, that the earth, itself, in common with all masses of matter, possesses an attractive power; that this power is only as much greater in the earth, as that body is larger than the bodies which surround it, or are upon it.

CHAPTER X.

Laws of Motion—Compound Motion—Composition of Forces—Projectiles.

There are three important laws with respect to motion.

195. 1. *A body remains always in a state of rest or of motion till compelled to change that state by some external force.* 2. *The motion of a body is in the direction of the force which produces it, and is proportioned to that force.* 3. *To every action of one*

194. Is the cause of gravitation known?—What have some philosophers asserted with respect to the cause of bodies falling towards the earth?

195. What are the three great laws of motion?

body upon another, there is an equal, and con reaction.

196. The first law of motion results from the *in* of matter. A body at rest requires more force t it in motion than to move it after it is started, be the inertia of rest is to be overcome. Thus wh body in motion is suddenly stopped, it experien shock.

197. With respect to the second law of motion, examples will show its application. If you wis toss an apple to some one, you understand that it *move in the direction which you give it*, and strength being rightly directed, the apple reach destined place. A north wind blows light bodies s or in the direction of the force. A south wind b towards the north.

198. The third law of motion, or that of action reaction, is also easily explained. A man in s ming, presses the water downward and backward his hands, and is borne upward and forward b reaction of the water. The bird flies by using wings as the swimmer does his hands; the air, b reaction, carrying him upward and forward.

Fig. 24.

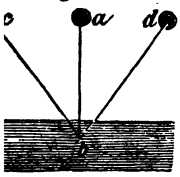
A boy one day attempted to lift self in a basket, but the harder he ed upward, the more his weight p ed downward, and, like many foolish people, he spent his stre for nothing. The same labor, and less, might have served to fill his ba with chips for the kitchen fire.

199. The rebounding of elastic bodies proves

196. What does the first law of motion result from?
197. Examples of the first law of motion.
198. Explanation of the first law of motion.—Why canno boy lift himself in the basket?
199. What does the rebounding of elastic bodies prove?- plain the figure.

on and reaction are equal; if a ball of ivory be pped perpendicularly, upon a marble slab, it will ound in the same perpendicular line; but if thrown iquely, it will rebound obliquely, though in an oppo-

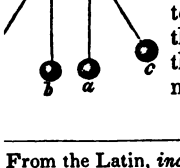
Fig. 25.



site direction. Suppose an elastic ball, *a*, to fall upon a hard substance, *b*; if it fall perpendicularly, or in the line *a b*, it will rebound in the same line *b a*; but if it fall in the oblique direction, *c b*, it will rebound in the line, *b d*. The first line, or *c b*, is called the line of incidence,* the second line, *d b*, the ɜ of reflection;† the more oblique is the line of inciıce, the more so will be the line of reflection. The *rle of incidence is always equal to the angle of ection;* thus the angle *a b d*, is equal to the angle *c*, because the line, *a b*, divides the larger angle, *c* , into two equal parts.

200. *When two elastic bodies, of equal weight and ɔcity, strike each other, the striking body communies the whole of its motion to the other, and then reins at rest.*

Fig. 26.



Thus, suppose two ivory balls of equal weight, *a*, *b*, be suspended by threads; if *a* be drawn up to *c*, and then let fall against *b*, it will drive it to *d*, or a distance equal to that through which *a* had fallen, while the latter, having imparted all its motion, remains at rest, as at *a*.

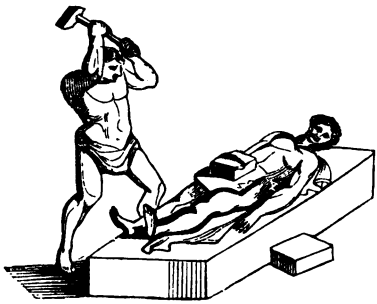
201. Philosophy explains things

From the Latin, *incidens*, which means falling upon.
From the Latin, *re* and *flecto*, signifying to throw back.

200. Effect of two elastic bodies striking each other. Example.
201. Explanation of the effect of blows upon an anvil lying a man's breast.

which the ignorant often ascribe to witchcraft or magic. It is recorded in history that Firmus, a German, who lived in the third century, performed many wondrous feats, which excited great astonishment. Among others, was that of suffering iron to be forged upon an anvil placed on his breast, while he lay extended on his back. Modern jugglers have excited equal astonishment by the same exploit. This feat, though a surprising one, exhibits only an illustration of the reaction of elastic bodies. The great effort is, in sustaining the weight of the anvil; for, when the blow is struck the man feels less of its weight than he did before, because, in its reaction, it rises towards the hammer. If the anvil were but a thin piece of iron, or if the blows were struck upon the breast, the man would be killed by them; but the more matter the anvil has, the greater is its inertia; and the quantity of motion is diffused through its mass, instead of acting upon the man who sustains the anvil.

Fig. 27.



Compound Motion.

202. *Simple motion* is that which is produced by the action of *one force*. A ball thrown by the force of a boy's arm is an example of simple motion. So is also a bullet shot from a gun, and an arrow from a bow.

203. *Compound motion is the result of two or more*

---

202. What is simple motion?
203. What is compound motion?

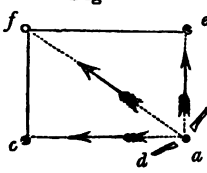
forces acting at the same time. If two equal forces act in direct opposition upon a body, it will not move, any more than the arms of a balance on which are suspended equal weights; the one force, as the one weight, balances the other.

204. If two men of equal strength pull upon any weight in opposite directions, it will remain at rest. The same principle seems to operate in the human mind. A man may be so equally urged by opposite motives, that though he feels it very important to act, he seems unable to do so. This painful state of mind, or indecision, can only be changed by a powerful effort of the will. Now as matter possesses no such controlling power, it must remain balanced so long as it is acted upon by *equal* force applied in opposite directions.

Composition of Forces.

205. When a body is acted upon by two forces, not in *opposite* but in *different directions*, it will move in a line between them. This union of forces is called the *composition of forces.*

Fig. 28.



206. Let *a* be a billiard ball; if it be struck by *b*, it will move in the direction towards *c*; if it be struck by *d*, it will move towards *e*; but if it be struck by both forces at the same instant, it will move in a line towards *f*. By drawing a line from *f* to *e*, and another from *f* to *c*, we have a figure called a *parallelogram*, and the line *a f* is the *diagonal* of the parallelogram.

---

204. Effect of equal forces acting in opposite directions.

205. How will a body move when acted upon by two forces, not in opposite but different directions?

206. Can you explain the figure illustrating the composition of forces?

ball from a straight line to a *curve*. The force of the gunpowder would drive the ball in a straight, horizontal line, and the force of gravitation, if uniform, would be in a straight line downward. In this case, the motion of the ball would be in a straight, diagonal line, between the two forces. But while the projectile force, or that which first impelled the ball, is uniform, acting once and then ceasing to act, gravitation is exerting at every instant a new force, and thus the resultant is a *curve* line.

Fig. 31.

The figure represents the cannonading of a town. The enemy are firing from behind their breast-work. The curved line described by the cannon ball is called a *parabola*.

212. The earth moves around the sun in a curve line, or in a circular path; this motion is supposed to be owing to the two forces, projection and gravitation. We may imagine that the Almighty, at creation, gave an impulse to the earth which would have carried it in a straight line; but the sun's attraction acting in a different direction, the earth began moving in a line between the two forces; and as the sun's attraction is

---

212. In what line does the earth move round the sun?—How is this motion supposed to be communicated?—What causes the motion of the moon?—What causes the motion of the planets, and their satellites?

every instant acting, the path of the earth is thus rendered *curvilinear*.

The moon, which is attracted by the earth, is in the same manner, kept moving around it in a circular orbit.

The motions of all the planets are supposed to result from the sun's attraction; while the motions of the moons or satellites around their primaries, are supposed to be owing to the attraction of the primaries.

PART II.

MECHANICS.

CHAPTER XI.

Simple Machines—The Cord—The Lever—The Inclined Plane.

213. Almost all kinds of labor are made easier and more useful to man by means of machinery. In the early ages, the tools or implements used by men in agriculture, in architecture, in domestic operations, or in war, were very rude; and manufactures, except the coarsest kind, were unknown. Even among the Romans, until the time of the Emperor Augustus, corn was ground by the women, in hand mills.

214. We now have clocks and watches moved and regulated by weights and springs. Here either the force of the weight, or the elasticity of the spring, is the moving power. We have mills that are moved by water, others by wind, others by steam. The strength of men and animals is made to act with a hundred fold more power, by the aid of machinery.

---

213. What effect do machines have upon labor?—What was the character of the first tools used by men?

214. How are clocks and watches moved?—How are mills moved?

215. There are *three* circumstances to be considered in all mechanical operations.

1st. The *weight* or resistance.

2d. The *force* or power by which it is moved.

3d. The *machines* by which the power is to be transmitted or modified.

216. The simplest machines are the *cord*, and *lever*, and the *inclined plane*.

The Cord.

217. If a man wished to move a log of wood, he might take it up in his arms and carry it. Here force is applied to overcome gravity, and it therefore acts in a *vertical* direction.

218. But let the man fasten a cord, or chain to the log, and draw it, his force will be exercised in a *horizontal* direction.

The cord then serves to transmit or *change* the direction of forces.

219. The manner in which the strength of the man, or the power used, is modified, is that instead of overcoming *gravity* by lifting the log, he merely overcomes *friction*, or the resistance caused by the log in rubbing against the ground which it passes over. In machinery, resistance of friction is rendered very slight by means of smooth and oiled surfaces.

220. The cord is used in a variety of ways to produce and transmit motion. Curtains are drawn *up* by pulling a cord *down*, bells are rung by means of a rope,

---

215. What circumstances are to be considered in mechanical operations?

216. Which are the three simplest machines?

217. Can you give an example of direct force applied to overcome gravity?—How does such force act?

218. For what purpose is the cord used?

219. What resistance is overcome by the use of the cord?—How is the friction of machinery rendered slight?

220. Give some examples of the common use of the cord.

and the complicated machinery of a ship is mostly moved by motion applied to ropes.

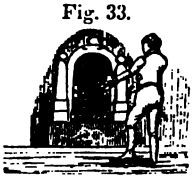
221. In spinning-wheels the *band* or cord connecting the rim with the head serves to communicate motion, and transmit force. In cotton and woollen manufactories, and wherever a thread is to be twisted, the cord or band is used to modify and transmit force.

Fig. 32.

222. You see a woman spinning. The cord which passes from the wheel to its head connects the two parts, so that when the woman's foot presses upon the board, which communicates with a crank, the pressure sets the wheel in motion; this motion is conveyed to the spindle, and from thence to the flax, which the spinner, by means of a distaff, holds in her hand, and the thread begins to twist, as she pulls out the flax to a suitable fineness. No exercise can be more healthful or graceful for a female than this, which was so common in our country a few years since; and we could almost regret the improvements in manufactures which have banished from the fireside the domestic spinning-wheel.

The Lever.

Fig. 33.

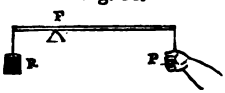


223. A man wishing to raise a large stone, or other heavy weight, and finding his unassisted strength not sufficient, naturally looks about for some iron bar, or strong stick of wood, and placing something firm for a prop, he thus *pries* up the weight. This bar or stick is a *lever* or *lifter* (as the word origi-

221. How is motion communicated to spinning-wheels?
222. Describe the operation of a spinning-wheel.
223. For what purpose, and how is the lever used?

nally signified,) and the prop is the *fulcrum*. A poker is a lever, when used for stirring the fire; the grate on which it rests is the *fulcrum*, the coals the *weight*, and the hand the *power*.

Fig. 34.

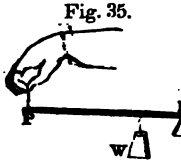


Lever of the first kind.

224. There are *three* kinds of levers. 1st. *The fulcrum, F, is between the pow r, P, and the weight, R.*

225. The common steelyard is a lever of this kind; the power is the weight of the steelyard, which is used to balance the *resistance* or article weighed; the *fulcrum* is that point on which the beam turns.

Fig. 35.

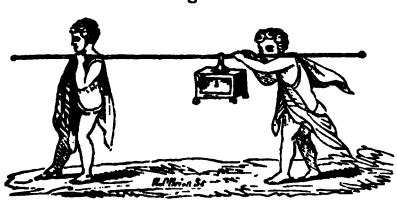


Lever of the second kind.

226. 2d. *The weight, W, is between the fulcrum, F, and the power, P.*

227. A pail of water, or any weight hanging upon a pole, and carried by two persons, is an illustration of this. The pole may represent a lever. If the arms are unequal, the person bearing the short arm of the lever sustains the greater weight. If the arms are equal, or the weight exactly in the middle, the burden is equally sustained by the two persons, one of whom

Fig. 36.



224. How many kinds of levers are there?

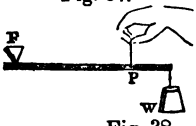
225. Describe the first kind.—How does the steelyard afford an illustration of this?

226. Describe the second kind of lever.

227. Can you give an illustration of it?

may represent the *power*, the other the *fulcrum*. this lever, therefore, the nearer the resistance is to fulcrum, the more it will be destroyed by it, or, in ot words, *the greater will be the power of the lever.*

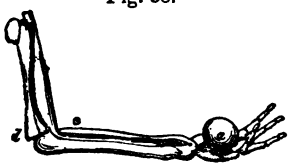
Fig. 37.



Lever of the third kind.

228. 3d. *The power, P, is tween the weight, W, and the crum, F.*

Fig. 38.



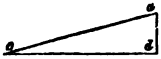
229. The bones of mals are levers of this ki The human arm may se as an example; the elbow is the *fulcrum*, at *e* is a m cle that acts as a *power* raising the weight, *a*.

The Inclined Plane.

230. When a man wishes to move a barrel dow declivity, he provides a strong plank and places it i slanting position, with one end resting at the top, other at the base of the descent. He can then ea roll the barrel down; or he may thus roll it up w much less force than would have been required to li vertically. This plank is an inclined plane.

231. Let *a c* represent an inclined plane, *a b* height, and *b c* its base. It is very evident that a wei might be more easily rolled up a slo *c a*, than raised perpendicularly at *i* but the advantage gained is at the pense of time; because, instead of m

Fig. 39.



228. Describe the third lever.

229. Illustration.

230. Can you give an example in which a man would make of the inclined plane?

231. You say we gain power by the use of the inclined plan we lose any thing in time?—Can you explain how this is?

irectly from *b* to *a*, the weight moves from *c* to *a*, sistance being less in proportion as the line, *c a*, ger than the line *b a*; therefore, *as the length of lane is to the height, so much is the resistance nished.*

. In improvements upon roads, high hills which very difficult of ascent, are cut down, so as to inclined planes, which require much less strength vel over, than abrupt acclivities.

. When a horse travels over level ground, he y drags the load, but does not lift it; the only ance is from friction, and this, being in propor- o weight, will, of course, be greater, as the load vier.

. In drawing a load up a hill, the horse has to act st the force of gravity, or, to lift a part of the t; and this part will be greater or less in propor- o the steepness of the hill.

CHAPTER XII.

Compound Mechanical Powers.

. The *cord*, *lever*, and *inclined plane* are applied ibination or connection with each other, in various forming what are called *compound mechanical*

How can you apply the principle of the inclined plane to king of roads?

When a horse is drawing a load on level ground, what re- e has he to overcome?

In drawing a load up hill what resistance has the horse to ne?

Are the simple mechanical powers ever used in connection ach other?—What are they then called?—What are the nd mechanical powers?

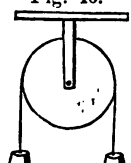
powers; these are the *pulley*, the *wheel and a wedge, and the screw.*

The Pulley.

236. *The pulley* is composed of the united pov the cord and lever; the radius or slope of the being the lever, and this is moved by means cord. There are two kinds of pulleys, the *fix* the *moveable* pulley.

237. 1st. The *fixed pulley does not increase p* its use is in changing the direction of the force a By the use of the fixed pulley, we *raise a body* means of *pulling down*, as in the case of windo tains which are raised by cords passing ove pulleys.

Fig. 40.



238. The power, P, and the weig if equal in force, will draw upon equ tions of the cord passing over th pulley or wheel, and remain balan that the power has no advantage o weight.

239. In order to produce motic power, P, must be greater than the v W. There is nothing gained in ve for the weight moves as fast as the power; tha pulling P down one inch, W is lifted up but on The fixed pulley, therefore, does not enable a raise a heavier weight than he could do by hi strength.

240. *The moveable pulley gives to the power ble advantage over the weight.*

---

236. Of what is the pulley composed?—How many k pulleys are there?

237. Does the fixed pulley increase power?—What is th it then?—Can you give an example of its use?

238. Why is there no advantage gained by the fixed pul

239. Can you move a weight by the fixed pulley, of tl force as the power you apply?

240. What advantage does the moveable pulley give?

241. B is a moveable pulley, connected with a fixed pulley, C. The weight, W, is attached to the moveable pulley, and as it bears equally upon the two parts of the cord which pass around the moveable pulley, the power, P, has to sustain but half the weight, in order to balance W. Thus, if the weight is twenty pounds, it may be balanced by a power equal to ten pounds; but this advantage is gained at the expense of velocity, as, for every inch that the weight is raised, two inches of rope must be drawn by the power.

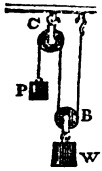


Fig. 41.

242. A tackle or block of pulleys increases the power in proportion as the coils or folds of rope are increased. Tackles are used for lifting barrels, boxes, heavy sacks, and packages of merchandize into the upper lofts in stores, and by sailors, for raising their sails up the masts. In the tackle most used by seamen, the pulleys are arranged, side by side, in two blocks placed one above the other. By means of four moveable pulleys, a weight of seventy-two pounds may be held in equilibrium by a power of nine pounds, because each pulley, having two folds of cord, each of which is equivalent to one half of the weight, we divide 72 by 8, and find the quotient to be 9. But the power must pass over eight times as much space as the weight; therefore *what is gained in power is lost in time.*

The Wheel and Axle.

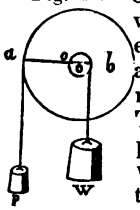
243. The wheel and axle is a lever of the first kind,

---

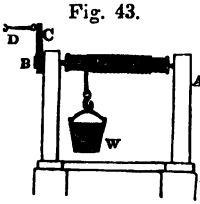
241. Can you explain the figure, and show how the moveable pulley gives a double advantage?—Is there any loss to set off against the advantage gained by the moveable pulley?

242. In what proportion does a block of pulleys increase power?—How many moveable pulleys will enable nine pounds to balance seventy-two?

243. Can you describe the wheel and axle?

in which *c*, the centre of the axle, represents the
Fig. 42. crum, *a c b*, a horizontal lever with


weight, W, and the power, P, at opp
ends. The radius or spoke of the w
acts as the longer arm of the lever, an
radius of the axle as the shorter
Therefore there is an equilibrium whe
power bears the same proportion to
weight, as the radius of the axle, *c o*, l
to the radius of the wheel, *o a*. Thu
the diameter of the wheel is ten times that of the
a power of one pound will balance a weight o
pounds.

244. The wheel and axle are used for drawing w
Fig. 43. from wells. In the common w


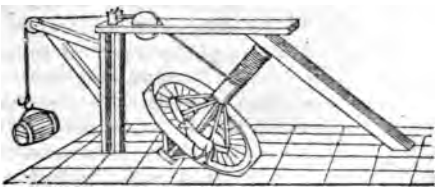
lass, the crank or winch, B C,
be considered the radius of
wheel. The power is applied a
handle, D. Therefore B C, re
sents the radius of the circle w
is described in the air by each r
lution of the crank; the power
be increased, in proportion as the circle describe
B C, is larger than the circumference of the axle,

Cranes for raising weights consist of an axle to w
up the rope which sustains the weight, and a l
wheel, at the circumference of which the power is
plied. The figure represents a machine of this k
in which an animal turns the wheel by treading wi
it, and thus by winding the rope around an axle, re
the weight.

---

244. How is the wheel and axle used for drawing water?

Fig. 44.



The Wedge.

245. *The Wedge may be considered as two inclined planes*, whose bases are joined. One of the most common instances of its use, is in splitting logs, which resist the ordinary force of the axe. A wedge of iron or wood is introduced into the surface of the log, and a few blows, with a mallet, or a common wooden instrument called a *beetle*, serve to cleave the log in sunder, by driving the wedge into it. Masses of granite and other rocks may be split in this manner. Axes, and all cutting instruments, are constructed upon the principle of the wedge.

Fig. 45.

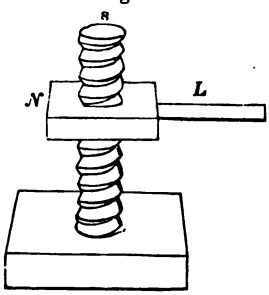
The Screw.

246. *The Screw is compounded of the lever and the inclined plane*, and has the advantage of these two mechanical powers united.

---

245. Describe the wedge.—For what purposes is it used?
246. Of what two powers is the screw compounded?

Fig. 46.



247. It has two parts, t screw *S*, and the nut, *N*. T *thread* of the screw, as t spiral protuberance is calle is an inclined plane. *L*, is lever which forms the hand of the nut; for the great the circumference which t curve would describe in o revolution, the more powe ful would be the action of t screw. *The closer the threa of the screw, the greater its power;* but this makes it necessary to use mo time in traversing them. Thus we find that what *gained in power, is lost in time;* and this we ha found to be the case with all the mechanical powers.

CHAPTER XIII.

Complex Machinery.

248. *Clocks* are complicated pieces of machiner When you look inside of a clock you perceive a pend lum swinging back and forth, and weights, wheels, an cords.

249. The pendulum rises, falls, and then rises again this is the effect of gravitation. When the pendulu is raised, gravitation brings it down with accelerat

247. Describe the screw as seen in the figure.—What effect h the lever on the power of the screw?

248. What can you say of clocks?

249. What causes the swing of the pendulum when put motion?

velocity, and the acquired velocity carries it upwards, and thus the action is continued.

250. Were it not for the friction and the resistance of the air, a pendulum once set in motion would never stop; but as these forces will, in time, obstruct all motion, it is necessary, in order to keep up the vibration of the pendulum, that some constant moving force should be in action. This force is obtained by means of a *weight* suspended by a cord, from a wheel, which gradually unwinding, moves a series of wheels with which it is connected.

251. *The office of the weight is to turn the wheels, and thus keep the pendulum in motion.*

252. When the pressure of the weight has drawn all the cords from a part of the machinery called the barrel, the *clock will stop.* It is set in motion again by *winding up;* that is, by winding the cord around the barrel, so that the gravitating force of the weight may again act upon the machinery.

253. Watches are not kept in motion by the force of gravitation acting upon a weight, but by means of *springs.* The *mainspring* of a watch answers the same purpose for communicating motion to the wheels, as does the weight of a clock. *A balance wheel* regulates the motion of the wheels of the watch, as the pendulum regulates the motion of a clock.

254. In mills of various kinds, we see examples of complicated machinery, wheels within wheels, all connected in *one system,* depending on *one moving power, and governed by one regulating principle.*

---

250. What causes a pendulum to stop?—What force is that in a clock which keeps the pendulum in motion?

251. What then is the office of the weight?

252. What will be the effect when the *weight* has drawn all the cord from the barrel?—How is the clock set in motion again?

253. By what means are watches kept in motion?

254. How are mills moved?

255. "By a visit to great manufacturing towns, or indeed, by simply directing the eyes to what is passing around us in any part of the civilized world, we discover miracles of mechanic arts:—machines driven by wind and water for grinding corn;—machines for sawing wood and giving it various forms.

256. Machines in which rods of metal are seized between great rollers, and are flattened at once into thin plates again are split into bars or ribbons;—Spinning machines, which perform their delicate office even more uniformly than human hands, forming thousands of threads at once, in obedience to the impulse of a single steam engine;—Weaving machines, which accomplish their difficult task with the most admirable perfection."

257. To these may be added "paper-making engines, which convert worn-out, and apparently useless remnants of our apparel, into a uniform and beautiful texture of paper, a texture which, with the farther assistance of the pen, or types, or engraved plate, becomes a magic conservatory of mind, shutting up among its folds the brightest effusions of genius, and ready at any instant to disclose them again to the inquiring student, nothing changed after revolving centuries."

258. To these we may add, "coining machinery, which divides and stamps thousands of beautiful medals in an hour, and keeps an exact record of its work:—cranes,—turning lathes,—time-pieces,—all the implements of agriculture, of mining, of navigation, &c. &c."*

* Arnott.

255. Can you give some instances in which machines are applied to useful purposes?

256. What other machines can you mention?

257. What is said of paper-making engines?

258. Coining machinery, &c.?

259. "In many of the complex machines, several of the simple ones are found as elements; and in the same machine may be comprised many of the means of changing the direction of motion.

260. Our views have hitherto been chiefly directed to solid bodies. All machines must be made of solid substances, in which the power of cohesion is so great as to bind together the particles of matter, so that the body may retain the form that is given it, and also be able to resist a certain degree of force.

261. When we think of the earth and the objects upon it, we may, at first view, imagine, that solids form the greater part of these substances; but this is far from being the case, for water and air occupy more space than solid bodies.

The mountains and the rocky portions of the earth, and the soil, the harder parts of vegetables, and the bones, sinews, and flesh of animals, are solids; and they are, in various ways, subject to the mechanical laws which we have endeavored to explain.

---

259. What are the elements of which the complex machines are composed?

260. Of what substances are machines made?

261. Do solids constitute the greater part of the matter which exists on the earth?

PART III.

HYDROSTATICS,

OR THE SUBJECT OF LIQUIDS.

CHAPTER XIV.

General Observations on Fluids.

262. We now advance to a branch of Natural Philosophy which leads us to the consideration of ***Fluid*** bodies. This branch is again divided into the study of *Liquids*, and of *Air* or gases; the former is called *Hydrostatics*, the latter, *Pneumatics*.

We shall first consider the nature of *fluids in general*, and then give our attention to the subject of liquids.

Fluids.

263. In solid bodies the particles are confined by cohesive attraction; in fluids they move freely *among each other, and give way to the least disturbing force.*

264. The same particles of matter, or atoms, may exist in the form of a solid or of a fluid. And when in a fluid state, they may constitute a dense liquid like water, or a light, elastic mass, like air.

---

262. Into what branches is the study of fluids divided?

263. Difference between solids and liquids.

264. Can the same particles of matter exist both in a solid and fluid form?

265. Thus the vast, unfathomable oceans, with the smaller divisions of water, seas, lakes, and rivers; the milk of animals, the blood which sustains life in the animal system, and the juices and sap of vegetables which answer the same purpose in the vegetable economy, as the blood does in that of animals;—these, with a great variety of *fluids*, are called by the general name of *liquids*.

266. *Air*, *steam*, *vapor*, and *gas*, are known by the name of *elastic fluids* or gases.

267. A pound of ice, a pound of water, or a pound of steam, differ only in the particles being more or less distant from each other, owing to their being more or less expanded by the different quantities of heat among them.

268. In ice, owing to the absence of heat, the particles are comparatively near to each other, and are held together by attraction; in water, the repulsion of heat seems nearly to balance attraction, and to leave the particles at liberty to glide about among each other, almost without friction; and in steam, the repulsion caused by heat overcomes the attraction, and the particles separate to a great distance.*

269. Whether matter be in a solid or a fluid state, the properties of the individual atoms, let them be ever so minute, remain unchanged; that is, the atoms always exist, in form and substance, in accordance with the general substance or body of which they are parts.

---

* Arnott's Physics.

---

265. Mention some of the liquids.
266. What are called elastic fluids?
267. How do ice, water, and steam differ?
268. How are the particles of water in ice held together?—Does the power of attraction act among the particles of water?—How is it in the case of steam?
269. What can you say as to the unchangeable nature of atoms?

270. The study of the laws which govern liquids when not in motion, is called *Hydrostatics.**

271. The study of flowing liquids, or liquids in motion, is called *Hydraulics.*†

272. The study of liquids in general, has been called *Hydrodynamics.*‡

But it is also common to consider the general science which treats of liquids, under the name of *Hydrostatics.*

273. Liquids may become solid by means of cold, or vapor by means of heat; thus water may be frozen so as to form a dense mass, called ice, or by heat it may be changed into steam, which is more light and elastic than the air itself.

274. Mercury is usually seen in the form of a very dense liquid; but, like water, cold may render it solid, and heat may cause it to boil and become a vapor.

275. The liquid state may be considered one in which *cohesion*, or the *attractive principle*, is exactly balanced by *heat*, or *the repulsive principle.*

276. At the common temperature of our climate, certain substances are in a solid state, while others are in a liquid state. But even solid bodies differ greatly in their degrees of solidity. Some cannot be broken with the most forcible blows, but, like iron and steel, strike fire under the hammer; others, like butter or lard, yield to the slightest force.

---

* From *udor* water and *statis* standing.

† From *udor* water and *aulos* a pipe.

‡ From *udor* water and *dunamos* power.

---

270. What is Hydrostatics?

271. What is Hydraulics?

272. What is Hydrodynamics?

273. How may liquids become solids?—How may liquids become vapor?

274. In what form is mercury usually seen? How may it be affected by heat?

275. How may the liquid state be considered?

276. Do solid bodies differ as to their degrees of solidity? Can you give some examples of this difference?

277. Honey, which is solid in the temperature of winter, becomes liquid in summer; and a very slight increase of heat serves to melt butter, and destroy its cohesion.

278. By raising the temperature to a certain degree, lead and tin, after dilating and becoming softer, appear in a liquid state; and gold, silver, iron, and even stones may be melted.

279. We have said, that the same particles of matter which compose a solid, may exist either in a liquid form or in that of vapor. The particles of matter are not changed when the water becomes ice, nor when it becomes steam or vapor; they are only closer together, or more influenced by cohesion in the ice than in the water; and in steam, the particles are separated still more by the repulsive principle of heat.

280. We see liquid particles collecting in drops, as in the case of mercury thrown upon a plate, or in the dew suspended upon the leaves of plants. These drops are formed by the cohesion of their particles. This cohesion is very slight, as appears from the ease with which the particles may be scattered.

281. As water is the most common of all liquids, it is this substance which is referred to in treating of the *mechanical properties of liquids.*

---

277. What effect has heat upon honey and butter?

278. What effect has heat upon lead and tin?—What other hard substances may be melted?

279. Are the particles of matter changed when water becomes ice or steam?

280. How are drops formed from liquids?

281. Why do we refer to water in treating of the *mechanical properties of liquids?*

CHAPTER XV.

Mechanical Properties of Liquids.

282. Liquids, like solids, are subject to the laws of gravitation, and in a greater degree in proportion as their cohesion is less.

283. Liquids can never be formed into figures, or kept piled up in heaps; thus, though the wind may raise water into waves, it soon sinks, overpowered by gravity.

284. *The level or equilibrium of liquids* is caused by the attraction of gravitation, operating on each particle and causing it to seek the lowest place. Thus, we always see liquids, when at rest, remaining in a horizontal position.

285. This level-seeking principle in liquids is the cause of the descent of water from the higher portions of the earth to the lower.

In constructing canals, it is necessary that a *level* should be preserved, and it would be useless to attempt to carry water higher than its source. Where there are irregularities in the ground, locks and aqueducts are made. Locks are a series of basins large enough to hold a canal boat, and sometimes even vessels; they have gates which can be lifted up for water to flow in, and then closed; in this manner boats are floated up

---

282. Are liquids subject to the laws of gravitation?

283. Can you form liquids into figures, or pile them in heaps?

284. What causes the level or equilibrium of liquids?—When liquids are at rest, in what position do we see them?

285. What is the cause of the descent of water from the higher to the lower portions of the earth?—What is necessary in constructing canals?—The use of locks and aqueducts.

hills; and by letting out the water from a series of locks, by means of raising and shutting the gates, they are also floated down hills. Aqueducts are made over

Fig. 47.

valleys, by means of which water is carried in a kind of bridge made tight at the bottom and sides, (as represented in the figure.) Aqueducts are also made over rivers, when it is necessary that a canal should cross them; and the canal traveller may sometimes look down and see vessels sailing in a stream over which he is floated, at a height of many feet from its surface.

286. The rain which falls on the tops of mountains and hills, if it encounter a soil not easily penetrable by water, collects in rills and small drains; these, soon uniting, form streams and rivulets, which, descending along the sides of the elevations, unite with other streams, and, as they descend into lower levels, at length swell into a river.

287. The waters, still having a tendency to descend, are governed in their course by the slopes of the ground

---

286. Can you describe how rain falling on mountains is formed into rivulets and streams?

287. What principle is it that causes rivers to flow through the lowest channels to the ocean?

over which they have to pass, always taking that course which most accelerates their descent. Sometimes descending into a spacious basin, they widen and spread into a large lake; again, being contracted between mountains or high lands, they rush through gorges and resume their former character of a river. After being swelled and increased by tributary streams, they at length arrive at their final destination, and restore to the ocean those waters which had originally been taken from it by evaporation. Throughout the whole of this process, the great principle in operation, is the tendency of a liquid to find its level.

288. In some cases, the rain which falls on elevated grounds meets a spongy soil, easily penetrated by water. In such cases, water often sinks to very great depths before it arrives at an impenetrable stratum or barrier. When this happens, the reservoir in which it is confined, is subject to great pressure from the water which fills the more elevated veins and channels by which it is fed. This pressure frequently forces the water to break a passage through the surface, and then it gushes out with great force, often loosening large masses of earth. An instance of this occurred in the year 1836, near the base of Mount Olympus, a high hill about half a mile east of the city of Troy, in the State of New York. Several persons were buried under the masses of earth which were thrown down, and one or two buildings were destroyed.

289. Those sublime natural objects, cataracts and waterfalls, are manifestations of the tendency of liquids to find their level. Rivers, while flowing along the bases of mountains in quest of a passage to the sea, at great elevations above its level, frequently encounter

288. What causes a reservoir of water sometimes to force a passage through the earth? What caused the breaking forth of Mount Olympus, near Troy?

289. What produces cataracts and waterfalls? Describe the cataract of Niagara.

abrupt declivities, down which they are precipitated in cataracts. The heights of the barriers over which some of the largest rivers in the world are precipitated, place these stupendous phenomena among the most sublime of natural appearances. In the great cataract of Niagara the breadth of the stream is four hundred yards immediately above the descent, and the agitated waters are precipitated through the perpendicular height of one hundred and fifty feet, throwing up a cloud of dense vapor to such a height that it may often be seen at the distance of twenty miles; and the awful roar of the cataract may be heard an equal distance.

290. The motion of water in rivers has a sensible effect in wearing away their bed. By this means, in the course of time, the face of a country may often undergo great changes.

291. The falls of Niagara are gradually changing their aspect by this cause; and it is probable that in the course of time, the barrier between these falls and lake Erie will be broken down, that inland sea be drained, and the space it now occupies converted into a fertile valley.

292. Rivers, while passing on to find their level, sometimes suddenly disappear and force their passage through subterranean caverns and channels; and after passing for a certain space under ground, reappear in their channels, and flow on the surface to the sea.

Exception to the General law respecting Water level.

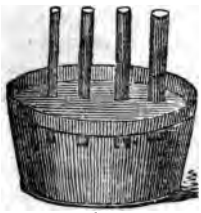
In certain cases, water rises above its level, as in the fibres of cloth which has one end dipped in water; a

290. What effect does the motion of water in rivers have upon their bed?

291. What may be the effect of such changes in the course of time?

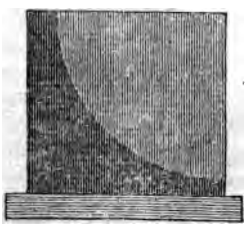
292. Do rivers ever disappear in their channels?

Fig. 48.



small piece of loaf sugar, h one end in a liquid, will soo at the opposite and higher very small glass tubes, liq also rise, and this phenon called *capillary attraction*, *pillus*, a hair, on account smallness of the tubes. The the tube, the more this kir traction is evident. The fig resents four glass tubes, of different sizes, plun a vessel of water; the liquid is seen to be high its level, as the tube is smaller.

Fig. 49.



Two plates of glas so that they touch side, and are slightl ted on the other, p similar effect on liqui pillary tubes. The shows in the dark water as it will ris such circumstances; umn being higher w plates of glass are le rated. This may be explained on the princi liquids spread and cohere together; thus if a water be placed on a plate of glass, it will exte and even if it be put on the under side of the will not fall off, but spread. Most philosoph sider capillary attraction to be caused by the a influence of the particles of glass which com tubes or plates.

293. As the particles of liquids gravitate i dently, they press against each other in every d

What is capillary attraction? Describe the figure.

293. Why do the particles of liquids press against eacl

Fig. 50.

294. The particles are not supposed to be piled one over the other in regular columns, as in the figure at A, but arranged as at B, ere each particle acts as a wedge upon those below pressing not only *downward*, but *sideway*.

Fig. 51.

295. The downward and sideway pressure produce, also, an *upward* pressure. It is this upward pressure which causes the liquid poured into a teapot to rise in the spout as rapidly as in the body of the vessel.

296. This may be further illustrated by pouring water into a bent tube of glass. Let A represent the opening at which the water is poured in; as fast as the liquid falls to the bottom at B, a portion will rise towards C; a small quantity would fill the bottom and rest at the level *d*; an additional quantity would raise the height of the liquid to *e*, and another portion would raise o *f*. Now, since the fluid rises from B to C con- ry to the laws of gravitation, we must refer the ce which causes its ascent to the *upward* pressure liquids.

. 53. If the communicating tubes are of different diameters, as in the figure, the fluid will, nevertheless, stand at the same height in both; from this arises the general law, that *a portion of liquid, however small, will resist pressure of a portion however large, and will bal- :e it.*

297. The *lateral* or *side pressure* is equal to the ssure either upwards or downwards.

)4. Are the particles of liquids piled one over the other in regcolumns?—How are they arranged?

)5. What causes the upward pressure of liquids?

)6. How can you illustrate this further?—What will be the :t if the communicating tubes are of different diameters?

)7. What can you say of the lateral or side pressure?

Fig. 54. Let a vessel, A B, be fille

two orifices of equal dimens
and *b*, the one at the bottom
side of the vessel. Let the
receivers, and it will be fou
given time, that the quanti
has flowed out, is equal in b
will be observed that the he
above *a* is no greater than the heig
wise the pressure would be greatest
liquid would flow out, in the same ti

298. The power of water pressu
static pressure, is very great. It h
ally applied in the constructing of
Hydrostatic press.

CHAPTER XVI.

Comparative Weight, or Specific G

299. A piece of cork dropped from

300. The *specific gravity* of cork is less, while that of iron is greater than that of water. By this we mean, that a portion of cork of the same bulk as a certain portion of water, would weigh less than the water, and that a bit of iron of the same bulk would weigh more than the water.

301. Specific gravity means the same thing as *comparative* gravity; thus we say, the specific gravity of silver is less than that of gold, meaning, that a square inch of silver would weigh less than a square inch of gold.*

302. It is said that water weighs nothing in water; by this is meant, that water in its own element, is supported equally by the pressure on all sides. Any substance having the same specific gravity as water, may also be said to have no weight in this liquor; for if it were first weighed in the air, and then weighed in the water, it would, in the latter case, be so supported by the water as not to bear with any weight upon the scale.

303. In drawing a bucket of water out of a well, it is found that the bucket rises with the slightest effort until it reaches the surface of the water, but in its passage through the air its weight is felt very sensibly. Were there no air, but a perfect void, the weight of the bucket would appear still greater.

---

* The author does not here give the rules for determining specific gravity; these are too complex for the beginner, but will be found fully explained in "Familiar Lectures on Natural Philosophy," chap. xxi.

---

300. Is the specific gravity of cork more or less than that of water?—How is this as to iron?—What do we mean by this?

301. Can you explain the meaning of specific gravity by a further example?

302. Can you explain why it is said that water weighs nothing in water?

303. Can a bucket be lifted more easily in water than out of it?—Would the weight be increased if there were no surrounding air?

474377

304. One man may lift a stone in deep water, which, on land, would require the strength of two men to raise. A person in bathing feels himself supported by the water so that he moves about in it with surprising ease.

305. *A body composed of any material, however heavy, may be so formed as to float upon any liquid however light.*

306. An earthen basin is composed of a material heavier than water; but if it be placed with its bottom downward on the surface of a tub of water, it will float. On observing the basin, it will be observed to be partly immersed in water, the space below the level of the fluid being occupied partly by the earthen bottom of the basin and partly by air. Now air being lighter than water, and the whole concave space of the basin being filled with it, the basin is supported or buoyed up in the water by means of this air, which, also, counterbalances the greater specific gravity of the basin when compared with that of the water.

307. If some water be poured into the basin thus floating, it will be seen to sink deeper; but air being still left in the basin, it continues to float. Fill it completely with water, and it sinks; for, though the specific gravity of the water in the basin, and that by which it is surrounded are the same, the specific gravity of the basin is greater than that of the surrounding fluid, and, unless buoyed up by some lighter body, it must sink.

308. Ships floating on water contain a large portion

---

304. Can a man move a stone more easily in deep water than on land?

305. Can a heavy body be so formed as to float in liquid?

306. Will an empty earthen basin float in water?—Can you explain the reason?

307. In what case will a basin sink?—Why?

308. Why do ships float on water?

of air. If the body of a ship fills with water, she must sink.

309. An iron boat may be made to swim; and if it be formed of double plates of metal, including between them a hollow space for containing a sufficient quantity of air, and made perfectly secure against the admission of water, it cannot sink, because it will displace more water than is equal to its own weight. That is, the whole iron boat, with the air included between its plates of metal and that which would naturally enter its concavity, weighs less than a quantity of water of equal bulk.

310. The *camel*, or a machine for lifting vessels over shallow water, is constructed upon the same principle. In the Zuyder Zee, in Holland, there are, in a certain place, sand banks upon which the water is so shallow as to prevent vessels of a large size from passing. This interruption to navigation was remedied in 1672, by fastening large chests filled with water, to the bottoms of the vessels; the water being then pumped out of these chests, they acquired a buoyancy of upward force equal to the weight of the water discharged. In this manner the ships were able to float over the shallow water.

311. *Life preservers* are also constructed on the same principle. A tube of India rubber surrounding the waist, is so fitted at one extremity that it may be filled with air by blowing with the mouth; the air is confined in the tube by a valve,* which also secures it against the entrance of water. Thus filled with air,

* A valve is a little door or flap, like a trap door, which may be opened in one direction, while force in the other only shuts it closer. The clapper in a common bellows is an example.

309. Can an iron boat be made to swim?

310. Can you explain the principle by which vessels may be lifted over shallow water?

311. How are life-preservers constructed?

it becomes light when compared with its own bulk of water, and so keeps the person from sinking.

312. The weight of the living human body does not vary much from that of its own bulk of water, or, in other words, its specific gravity is about the same as that of water. But, in drawing the breath, the chest is filled with air, and then the body is somewhat lighter than its own bulk of water. When the breath is thrown out, the lungs are emptied of air, and shrink up or collapse; in this situation the body will sink deeper than when the lungs are inflated, or the cavity of the chest filled with air. It is said that a person lying perfectly still on the surface of water, would not entirely sink, but in raising his limbs out of water his head sinks in proportion.

313. As sea-water is heavier than rain or fresh water, a swimmer is more buoyed up in it, and can therefore swim with less effort than in fresh water.

314. A vessel so heavily laden that it would sink in fresh water, may float in salt water.

315. The bodies of ducks, geese, and other water-fowl, are much lighter than their own bulk of water. Their feathers render them more buoyant.

316. Fishes are furnished with air vessels, so that they can enlarge their bulk, and thus lessen their specific gravity. When these air vessels are filled, the fish displaces more water than its own weight, and rises to the surface. When the fish expels the air from its air vessels, it shrinks into less bulk, displaces less water than its own weight, and sinks to the bottom.

---

312. Is the human body heavier or lighter than its bulk of water?—How may the body be made lighter than its bulk of water?

313. Why can one swim with less effort in sea-water than in fresh water?

314. Will a vessel bear more weight in salt water than in fresh?

315. Why are waterfowls lighter than their bulk of water?

316. What changes the specific gravity of fishes?

CHAPTER XVII.

Hydraulics, or Water in Motion—Hydraulic Machines.

317. When water flows out of a deep vessel from an orifice at the bottom, the surface descends first in a horizontal manner, then it begins to lower in the centre, till, at length, when the surface is considerably lowered, it appears in the form of a funnel.

Fig. 55.

318. This is illustrated by the figure, in which the lines, first horizontal, and then gradually becoming more perpendicular, show the changes which take place in the surface of the water.

319. The velocity with which water spouts out at orifices in the sides of a vessel, will be proportioned to the distance of each orifice from the surface of the water, or to the perpendicular height of its column. Thus in drawing liquor from a cask, should three tubes be placed at different distances from the bottom, and receivers be set under each spout, the vessel under the lowest spout would fill most rapidly, and the middle one would fill more rapidly than the upper one.

320. The projectile force at each spout would be in

317. When there is an orifice in the bottom of a deep vessel, how does the water flow from it?

318. Can you explain the figure?

319. What is the proportionate velocity with which water spouts from orifices in the sides of a vessel?—Can you explain this by an example?

320. How is the projectile force at each spout estimated?—Which

proportion to the velocity with which the fluid issu and therefore greatest at the lower spout, and least the upper one. The projectile force of a spouti liquid may be estimated by the distance to whicl stream issuing from an orifice, will be propelled. Th if an orifice be made near the bottom of a cask fill with liquid, the liquid will spout to a greater distar than if the orifice is made near the top of the cask.

321. A current of water will give to the air arou it, a motion in the same direction. If a feather, other light substance be suspended over the surface a rapid stream, it will have a tendency to move alo in the direction of the stream. This effect upon t air is greater in proportion to the velocity of t stream. Whoever has stood upon the banks of t Niagara, near the rapids of that river, must have o served the powerful effects of the velocity of the agi ted waters, upon the surrounding atmosphere, not on in producing sound, but also currents and gusts of ai

322. These effects are supposed to be owing to fr tion between the particles of water at the surface the stream, and those of air in contact with them. the same cause is ascribed the agitation of the sea the wind, and the transformation of its surface, dur a storm, into foaming waves and mighty billows.

323. Dr. Franklin proved that pouring oil on wa agitated by wind, caused its rippled surface to beco calm. Even the violence of the sea has been th abated, and its waves have sunk into calm repo The oil being lighter than water, forms a floating fi which defends the surface of the water from cont

orifice will throw the liquid the greater distance, one near the tom of a cask or near the top?

321. What effect does a current of water have upon the mo of the air around it?—Is this apparent near great water falls?

322. To what are such effects supposed to be owing?

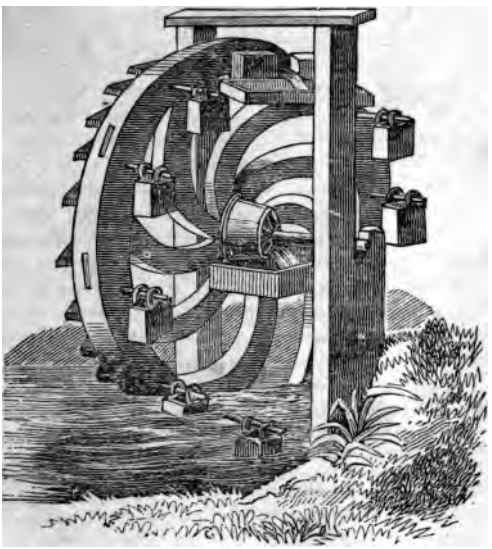
323. What is the effect of pouring oil on water agitated by wi —Can you explain how oil has the effect of calming agit waters?

with currents of air, thus greatly diminishing the friction between the wind and waves, as oiling the surfaces of solids diminishes the friction of rubbing surfaces.

Hydraulic Machines.

324. These are of three kinds; 1st. Machinery for raising water by mechanical means only, as in the common well, when water is lifted by means of a bucket and windlass. There are different kinds of machines of this class, much more efficient and powerful than the common windlass, as the chain-pump, rope-pump, &c.

Fig. 56.



324. How many kinds of Hydraulic machines are there?—Describe the first kind.

325. The Persian Wheel, which is us
in the eastern countries, consists of
having upon its rim a number of bu
wheel revolves in the water, the bucke
sively filled, and as they rise, are tilted
chinery into a cistern fitted for the rec
water. Thus the buckets are constantl
emptying themselves, by the turning of th
326. 2d. The second class of Hydrauli
are those which act on solids, by the weigh
sure of water. Of this class are water w
great variety of constructions, such as you r
mills and manufactories of various kinds.
327. 3d. There are machines in which the
produced by the reaction or intermitting force
ing water. Among these, is the Hydraulic R
vented by Montgolfier, a celebrated mechanic
France, and the invention of the balloon. The H
lic Ram operates chiefly from the momentum
current of water suddenly stopped in its course
made to act in another direction; and, as it prod
a kind of intermitting or irregular motion, owing
the alternate coming and going of the stream, acco
panied with a peculiar noise, arising from the shoc
its action has been compared to the butting of ram
and this has given name to the machine.* This i
considered one of the most simple, useful and philoso-
phical of the Hydraulic machines.

* Called in French *Belier Hydraulique.*

325. Describe the Persian wheel.
326. What is said of the second class of Hydraulic machines?
327. Of the third class?--Who invented the Hydraulic ram?--
Can you explain how it operates?

CHAPTER XVIII.

General summary of Hydrostatics.

. Water is transparent, without color, taste, or
It is heavy, and has little elasticity. It can-
sily be compressed into less bulk. It is called
elastic fluid, while air, which can be easily com-
d, is called an *elastic fluid.* Water may become
l by cold, and vapor by heat; when solid, it is
ice, when a vapor, it is called steam. Water
s seeks its own level. It is subject to gravita-
nd capillary attraction. Its particles press equally
directions.

. When water boils away, (to use a common ex-
on,) the particles are driven off by heat, and
ito the air around, but no one particle is lost or
yed. Steam may be changed back to water by
plication of cold. If a current of cold air, be
o a room which is so filled with steam that one can
ly see across it, the steam at once vanishes,
ops of water cover the windows and ceiling of the
The steam was condensed by the cold air;—
, the watery particles, being cooled, drew closer
er, and formed themselves into drops.

. Water left in an open dish, slowly passes off
ie air; this is called *evaporation.* The water in

Mention some of the qualities of water.

Explain the process of "*boiling water away.*"—Are the
s of water lost by boiling away?—How may steam be
d to water?

When you leave water for some time in an open dish,
ecomes of it?—Does the water in sea, rivers, &c., evapo-

seas, rivers, lakes and ponds evaporates; it goe the air and forms clouds, and descends to the again in rain, snow, or hail.

331. If the floor of a room be wet in a warm the air will be cooled and refreshed by the moi arising from the evaporation of the water.

332. When water is solid or becomes ice, it is li er than in the liquid state, and rises to the surf Were it not for this wonderful provision of Provide in departing, in this instance, from the common pri ple that the loss of heat and consequent solidifying bodies, makes them heavier, rivers and lakes and eve body of water subject to frost, would become one sol body of ice. If ice were to sink as soon as forme the upper surface of the water being again exposed t a cold air, would freeze, and another layer or stratu of ice would sink, leaving another portion of water t undergo the same change.

333. This process would continue to go on until t the waters on the globe would become one solid bod of ice. The heat of one summer could have but lit effect upon the ice which would be accumulated duri one winter; and this increase of ice would grea add to the cold of the succeeding winter;—thus t change of seasons would soon cease, and winter, dre winter, would reign

"Sole monarch of the year."

Vegetable life must then cease; for what plant co long endure the severity of uninterrupted cold

331. What is the effect of wetting the floor of a room in a w day?

332. Is ice lighter than its bulk of water?—Does not thi pear to be different from the common principle that governs and liquid bodies?—What would be the effect on bodies of w if ice were to sink as soon as formed?

333. What would be the general consequence if this pr were to be long continued?—What would be the condition o world in such a state of things?

frost? The vegetable food necessary for animals being cut off, they might for a time, prey upon, and devour each other; but this work of destruction would be rapid, and the various animal tribes, with man, the lord of all, would disappear from the earth. This world, now so beautiful, so abundant in fruits and flowers, in food for man and beast; so full of life with its sportive insects, its playful and happy animals, its flying fowls of the air, and swimming fishes of the sea, its human population active in the business of life, perfecting improvements, and admiring and adoring the Great Giver of all;—this world, instead of presenting so bright an aspect, would soon, but for that one interposition of God, become the cold and frozen tomb of all vegetable and animal life.

334. But though man often sees his best and wisest plans defeated, through some oversight or mistake of his own, God is never forgetful, never mistaken, never unwise, and we may add, never unkind to his dependant creatures.

---

334. God's plans never defeated.

PART IV.

PNEUMATICS,

OR THE SUBJECT OF AIR, VAPORS, AND GASES

CHAPTER XIX.

Air—Compressibility of Air—Effect of Heat upon Air—Air-Pump—Piston and Cylinder.

Air.

335. *Pneumatics* is that branch of Natural Philosophy, which treats of air, vapor, and gases; the term is derived from the Greek, *pneuma*, signifying breath or air.

336. The air is like a vast ocean surrounding the globe, about forty-five miles in depth. It is as necessary to us, as water is to fishes, and we move about in this atmospheric ocean, as fishes do in their element. When a fish is taken from water, it appears to suffer great distress, and then dies. If a land animal is, for a few minutes, deprived of air, the same effects take place.

335. What does Pneumatics treat of?

336. Of what extent in depth is the air around the globe?—Is it *necessary* to animal life?

337. While men are thus surrounded by air and supported by its aid at every instant of their lives, there re many who scarcely think of its existence, because ıey do not *see it.* It is so with respect to the Great od who made us and keeps us alive; because we do ot see Him, we often doubt his existence, or forget ıat "He is about our bed and about our path, and ɔieth out all our ways."

338. The air seems in many respects not only a serant and agent, but a representative of the Almighty;— is in all places, and though unseen, is at every moıent giving us life.

Compressibility of Air.

339. Air is called an *elastic fluid;* it is easily *compressed* so that it may be made to occupy a smaller pace, and, on removing the pressure, it expands again. ake a tumbler which, (though we say it is empty,) is full of air, and plunge it downward into a larger tumbler of water. The water rises in the small tumbler, but does not fill it; there is a space above the water which seems empty, this space is occupied with the air which before the water was let in, filled the small tumbler; the bulk of this air is now lessened by pressure.

Fig. 57.

337. Why is it that many people scarcely think of the existence f air?

338. How does the air seem to be an emblem of God?

339. What is air called?—Can it be compressed?—Explain the gure.

Fig. 58.

340. A pair of bellows may serve to show some of the properties of air. On the lower board of the bellows is a large opening covered inside by a stiff piece of leather, called the clapper. This clapper is a *valve*, or little door, which is capable of being opened inwards, by the lightest pressure from without. When the bellows is opened, there is a vacant space within, and the external air pressing on all sides, rushes in to fill this vacuum. When the bellows is thus filled with air, and you attempt to press the two sides together, the air cannot pass out at the clapper because the pressure within keeps it down close over the aperture; there is but one vent for the confined air, and this is through the nozle of the bellows, from which it will rush in a powerful manner.

341. That the stream of air thus forced out by the bellows has weight and velocity, and, of course, momentum, you can ascertain by its effects, directed towards light bodies, it can, like a blast of wind, blow them about; it can, by its force, extinguish a lighted candle, and cause fire to burn with greater force and brightness.

The experiment with the bellows proves, first, that air has bulk, because, by it, the bellows is swelled out or expanded in size; second, it proves that when there is a vacant space or a *vacuum*, air will rush in to fill it; third, it proves that air may, by pressure, be forced from one place into another; and fourth, that it has weight, and can, when in swift motion, be made to exert power over other bodies.

---

340. Can you show some properties of air by a common bellows?

341. How do you know that air forced from a bellows has weight and velocity?

What does the experiment with the bellows prove?

Effect of Heat upon Air.

342. Air is expanded and rendered lighter by heat.

Fig. 59.

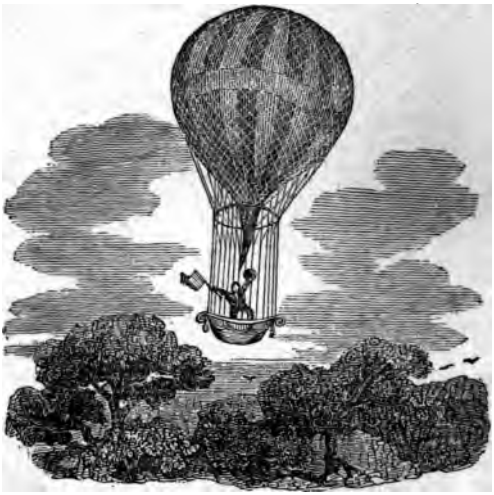
There are few children who are not familiar with the operation of blowing bubbles with soap and water. The soap renders the water so adhesive that by blowing the mixture, or suds, a thin hollow globe is formed, which is filled with warm air from the breath. This bubble, being filled with air lighter than that of the room, rises like a little balloon, and floats about, until the expansive force of the confined air bursts its envelope; the latter, no longer buoyed up, falls to the floor, as any other particles of water would do in the same situation.

The first balloons made were filled with heated air. These were invented by Montgolfier* of France. The

* The young pupil may be interested to know that a daughter of this gentleman, *Mademoiselle Adelaide Montgolfier*, is one of the first writers in France, and especially devoted to the improvement of the young. Those who can read French, would do well to obtain the interesting and instructive works of this lady and her friend, Madame Belloo, who is engaged with her in preparing a series of most excellent juvenile books.

342. What causes soap bubbles to rise?—With what were the first balloons filled?

Fig. 60.



balloons now used are inflated with a kind of ga which is, at all known temperatures, much lighter th the air. The heated air-balloon, besides being attend with various other inconveniences, would fall as so as it became cooled in the higher regions of the atm sphere.

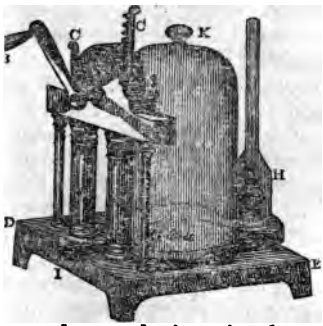
Air-Pump.

343. Air can be pumped out of a vessel until it empty or exhausted; but as the air on all sides wo

* Hydrogen gas.

343. Can you pump air from a vessel?—Can you describ air-pump?

Fig. 61.



rush in to fill the vacuum, the vessel from which the air is to be pumped, must be perfectly secured, so that no crevice whatever can admit the external air. The figure represents an air-pump; **A A** are brass barrels or cylinders which alternately rise and fall during the operation of pumping out the ; and as each rises, it takes with it a portion of air m the glass receiver, **K**. **C C** are piston or pump ndles which move up and down in the barrels; **B** is crank, by which a wheel is turned, whose revolv- motion causes the perpendicular motion of the pis- is. **D E** is a frame of mahogany which supports the ole; **I** is a screw, by the turning of which air from thout is admitted into the air-pump; **H** is an instru- nt called a barometer, which serves to show to what tent the air is pumped out of the air-pump, or as it usually expressed, *exhausted.*

Piston and Cylinder.

344. It is necessary towards understanding something of pneumatics that you should comprehend the operation of the *piston* and *cylinder*. *a* is the handle of the piston rod *d*; *c* is the piston, which is covered with leather, and oiled so as to slide freely up and down the cylinder or barrel, *a b*, without admitting any air. If the cylinder be tight at the bottom, and there be no opening in the piston, the air, which filled the whole cylinder, may, by forcibly pushing down the piston, be crowded or condensed into a very small space. In pushing down the piston, there is constantly a greater resistance, for the more the air is condensed, the greater is its power of resisting pressure, and the more force it exerts to escape from this pressure.

Fig. 62.

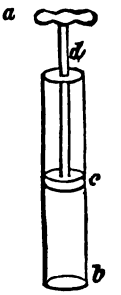
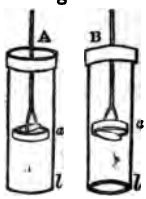


Fig. 63.



345. A piston may have in it a valve which shall admit air either from above or below. Let *A b* be a cylinder with a piston *a*, this piston has a valve or little door which opens upwards; every time the piston is pushed down, the air below being subjected to pressure, pushes up the valve and escapes, while no air from above can enter, because pressure in that direction would shut the valve. The pistons in the barrels of the air-pump have valves which open upwards, so that at every stroke, air rushes upwards as water rushes from the spout of a pump.

B b is a cylinder having a piston *a* with a valve opening downwards. At each stroke of the piston a por-

344. Can you explain the piston and cylinder?

345. What is the effect of a valve which opens upwards? What is the effect of a valve which opens downwards?

tion of air escapes through the valve downwards, and thus instead of exhausting the receiver, air is crowded in, or condensed.

CHAPTER XX.

Condenser—Experiments with the Air-Pump—Experiments with the Condenser.

346. Any body is said to be condensed when the particles of which it is composed are brought nearer together, and the same quantity of matter is made to occupy less space. A light biscuit may be squeezed in the hand, till its bulk is greatly diminished, though its substance is not lessened. Wool may be greatly condensed by pressure. A basket may be full of wool, and yet, ten times the weight of the first portion may, by pressure, be added to it. Air has been compared to wool in respect to its capacity for being condensed; and the different portions of the atmosphere, have been compared to a huge pile of fleeces of wool, in which the lower fleeces, by bearing the pressure of those above them, become more compact or dense than the upper ones. Thus the atmosphere becomes lighter as we ascend from the surface of the earth.

---

346. When may any body be said to be condensed?

Fig. 64.

347. The figure represents an apparatus called a *denser ;* its action is directly opposite to that of the pump. The condenser has a brass cylinder or b at A, containing a piston with a *valve opening d wards.* On raising the handle of the piston, *a*, the pressing down, opens the valve, and is forced thr a tube into the glass vessel or receiver, the latt held down upon the plate, *c*, by the cross-piece D, the screws, F E. At G, is a stop-cock, on tur which the condensed air in the receiver is made to out.

---

347. Describe the condenser ?

Experiments with the Air-Pump.

348. Many curious and interesting experiments may be made with the air-pump; it is one of the most useful and important instruments of a philosophical apparatus. By philosophical apparatus in its technical application, is meant such machines, instruments and inventions as serve to explain and illustrate the different principles of natural philosophy. Students who have the opportunity of examining these instruments, and of seeing their various uses and applications, have a great advantage over those who are not thus favored. More can be learned, in a short time, by the sight with respect to the nature of machines, than by a great deal of hard study. But every mechanic's shop, every mill and manufactory, exhibits, in its various machines, philosophical apparatus, and these every young person may have an opportunity of observing.

349. The air-pump has no *practical use* in mechanical operations; *it is wholly a scientific machine*, and though it illustrates principles in some degree familiar to all, it is only used by those who study the theory of philosophy.

350. By the theory of philosophy, we mean the principles on which it is founded. There are many practical mechanics who know nothing of the principles on which their operations depend; but who work by chance, or according to rules which have been given them by others, equally ignorant of the laws of motion, or of discoveries in relation to mechanical powers and moving forces.

351. Let it not be said that boys who are to learn

348. What is said of the importance of the air-pump?—Philosophical apparatus?
349. Is the air-pump of practical use in mechanical operations? By whom is it used?
350. Difference between theory and practice.
351. Is theoretical knowledge of any use to the practical mechanic?

trades have no need to study philosophy. Som
ledge of *theory* will be of great advantage to
practice, and will open to their minds new and e
views of the nature and importance of their bu
it will enable them to perceive in what way t
best improve and increase the advantages whic
offers.

352. It is from the mechanic who unites the
practice that we may expect new inventions a
coveries, such as neither the philosopher in hi
nor the ignorant and unthinking mechanic will b
to make.

353. By means of the air-pump, we are en
see what effect the absence or deprivation of
upon animal life. Let an insect, or any small
be put under the receiver of an air-pump afte
been exhausted of air, and it soon ceases to
A plant in the same situation will soon wither
A bell will not sound under an exhausted recei
air is the medium of sound, or the messenge
carries it from one place to another, and there
no sound where there is no conducting medium

Pressure of Air.

354. The receiver of the air-pump, when ex
of air, is held fast to the plate by the pressure
air from without. On turning the screw which
air into the receiver, the latter may be easily
The reason of this is, that air, like water, pr
all directions. When there was no air within
ceiver, there was nothing to resist the outward p
but the glass cover, and this was so powerful

352. From whom may we expect new inventions an
eries?

353. What are some of the experiments which may
with the air-pump?

354. Why is the exhausted receiver held fast to the pl
air-pump?—What is the effect of admitting air within the

pon by that pressure as to render it impossible, with slight force, to move it. As soon as air is admitted nside, there is within a pressure which resists the outrard pressure, and sets the receiver free from the conning force.

Weight of Air.

355. By means of an air-pump, the weight of air is roved. If a bottle, uncorked, be weighed in the air, nd afterwards be placed under the receiver of the air-ump and weighed, it will be found to weigh less than hen full of air. By this experiment a quart of air has een found to weigh eighteen grains.

Elasticity of Air.

356. The *elasticity* of air is proved by the air-pump; y elasticity we mean that when air is compressed it xerts a force to remove or throw off the power that ompresses it. A very small portion of air confined n a bladder, will expand under the receiver of an air-ump, and distend the bladder by pressing upon its ides. The expansion of the air in the bladder is aused by the removal of the external pressure of the ir, within the exhausted receiver. A very small por-ion of air may thus expand and fill a space compara-ively large.

357. An apple when dry and shrivelled contains within it particles of air; when the external pressure of the air is removed, by placing the apple under an exhausted receiver, the confined air will expand, and swelling out the skin, cause the dried apple to appear fresh and full. A bunch of raisins may in the same manner be made to look like a cluster of fresh ripe grapes.

---

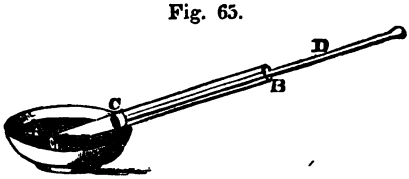
355. How does the air-pump prove the weight of air?
356. How is the elasticity of the air proved by the air-pump?
357. Effects produced upon dried fruit under the exhausted receiver.

Experiments made with the Condenser.

358. Experiments made with condensed air exhibit appearances very different from those made with the air-pump. A bell sounds louder when rung in condensed air than in common air. A thin glass vessel containing common air, and closely corked, will be broken inwards by the pressure of condensed air.—Fresh fruit will become shrivelled by the compression of the air within, by means of the elastic force of the denser air around it.

359. Boys are fond of making little air-guns, by means of which they are able to condense the air, so as to shoot wads, or pellets of tow, or paper. An elder stock, with the pith out, furnishes the cylinder; a walnut stick, nicely fitted to play in it, serves for a piston rod, and two wads of tow or paper, of size to move air-tight in the cylinder, serve, alternately, for a piston and a bullet. Every ingenious boy, will wish to prove, by his own inventions, the scientific pretensions of the pop-gun, and we think he will take more pleasure in this from understanding that it is a *condensing cylinder.*

Fig. 65.



360. For discharging water, a hollow elder stick, A B, (fig. 65) will serve for a cylinder, a plug of solid wood, C, forms the piston, D is the piston rod, a vent or small hole is made in the end of the cylinder, at A, for the purpose of admitting and discharging water.

358. What experiments can be made with condensed air?
359. On what principle is the boy's pop-gun constructed?
360. Describe the operation of the syringe.

On dipping the end of the cylinder A, into a vessel of water, and pushing down the handle of the piston, the air is forced out, and on drawing up the piston, water rushes into the cylinder to supply the vacuum. When the piston is again pushed down, the water may be driven out with a force sufficient to carry it several yards. The common syringe is constructed on the same principle.

CHAPTER XXI.

Barometer.

361. The barometer* is an instrument which is used for the purpose of weighing the atmosphere.

362. It may appear impossible that a column of air, extending forty-five miles in height, should be weighed by any instrument which man can invent. But, by various experiments, it has been proved, that a column of water, 34 feet high, will balance a column of air extending from the surface of the earth, through the whole atmosphere, or forty-five miles. Mercury or quicksilver is much heavier than water, so that a column of quicksilver, 30 inches high, will balance a column of water, 34 feet high; therefore, a column of quicksilver 30 inches in height, will balance a column of atmospheric air.

---

* The word barometer is from two Greek words, *baros* weight, and *metron* measure, signifying a measure of weight; but its meaning is confined to measuring, or determining the weight of the atmosphere.

---

361. Use of the barometer.

362. How high a column of water will balance a column of the atmosphere?—How high a column of mercury is required to weigh as much as a column of the atmosphere?

363. When one end of a syringe or hollow cylinder is immersed in water, we have seen that as the air is expelled by the action of a piston, water rushes up to fill the vacuum. This effect is caused by the weight of the atmosphere, which is pressing on all sides; this pressure upon the surface of the water, forces it up into the vacant cylinder. As long as this cylinder was filled with air, there was a pressure within, as well as without, and this was sufficient to resist the external pressure.

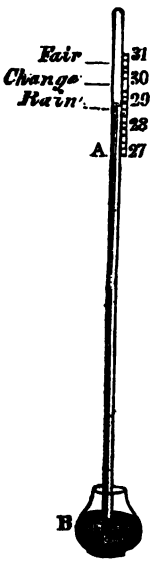
364. A common water-pump, like the cylinder, has one end immersed in a spring or well of water, and is furnished with a piston (whose handle is called the pump-handle,) to expel the air. The valve in the piston opening upwards, lets off the air in the cylinder or pump-barrel, and, as soon as the air is expelled, water rushes up to fill the vacuum. If water did not sustain the pressure of the atmosphere, it would not be thus forced up a tube, as soon as the air, which before filled it and resisted pressure, is removed. But water will not rise in a pump more than thirty-four feet high, because a column of water of that height balances the column of air, or atmospheric pressure. Two substances of equal weight, though of different bulks, may balance each other in a pair of scales. It takes a large pile of feathers to balance a leaden weight of fifty pounds. So as air is very light, it takes a column more than forty miles high, to balance a column of water as high as a common two-story house.*

* It must be understood by the pupil, that the columns are supposed to be of equal diameters.

363. What causes the water to rush up into the syringe when the air is expelled?

364. Why does the water rise in the water-pump after a few strokes of the piston?—How high will water rise in the water *pump*?—Why will it not rise higher?

Fig. 66.



365. We will now examine the barometer. A tube, A, of nearly three feet in length, closed at one end and open at the other, is filled with quicksilver, and then inverted in the cup B, which also contains quicksilver. The mercury or quicksilver will fall in the tube, to that point where the weight of its column is balanced by the weight of the atmosphere.

366. The air varies in weight according to the state of the weather; thus, when the pressure of the air, or its weight, is greatest, the barometer rises as high as thirty-one inches, and sinks, when the air is lightest, to twenty-seven inches. As the water of the syringe and pump is forced up the vacuum in the cylinders by the pressure of the external air, so the pressure of air, acting on the quicksilver in the cup, supports the column within the tube of the barometer.

367. In fair weather, the air is usually heavier than in stormy weather; though, from its effects on our feelings, we say, in bad weather, the air is heavy. It is a light or rarefied atmosphere, that renders breathing more laborious, for when we breathe in such an atmosphere, we take into our lungs a less portion of air than if it were more dense.

---

365. Describe the construction of the barometer.

366. How high will the mercury in the barometer rise?—How is the mercury supported in the tube of the barometer?

367. When is the air most heavy?—Why do we breathe less freely in a rarefied atmosphere?

368. When the atmosphere is light, vapors are not buoyed up, but hang in fogs over the surface of rivers and upon the sides of mountains, and smoke falls, instead of rising.

369. A sudden fall of the barometer indicates the approach of bad weather.

370. Barometers are used for determining the height of mountains. For every thousand feet of elevation, the barometer falls one inch. Thus, in ascending a mountain, when the barometer falls half an inch, we may consider ourselves at an elevation of five hundred feet.

---

368. What causes vapors to hang in fogs, in the lower portions of the atmosphere?

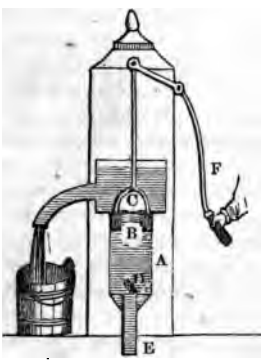
369. What is indicated by a sudden fall of the barometer?

370. How are barometers used for determining the height of mountains?

CHAPTER XXII.

*Pumps—Fire Engine—Syphons—Intermitting Springs.**

Fig. 67.



371. The common suction pump consists of two hollow, cylindric pipes, a larger one, A, communicating with a smaller one, E. At D is a valve opening upwards, and affording communication, when open, with the upper cylinder or barrel of the pump, A; in this cylinder is the piston, B, with a valve, C, opening upwards; the water rising above this valve is discharged at the spout. When the lever handle, F, of the piston rod is lowered by the force of the hand, the valve, C, will be closed by the pressure of the air above, and a vacuum being thus formed in the pump barrel, the pressure on the surface of the water in the well will drive it up the suction pipe, (as the cylinder at E is called), and raising the valve, D, the water will

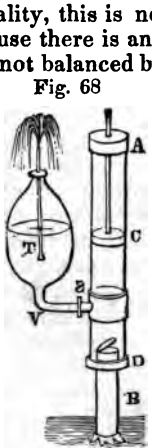
* The subjects treated of in this section may seem to belong to the department of Hydrostatics; but as the action of pumps, syphons, and intermitting springs, depends on atmospheric pressure, and cannot be understood without some knowledge of this subject, a consideration of them under the head of Pneumatics appears proper.

371. Describe the common suction pump.

rush up to fill the vacuum in the exhausted barr
again pushing down the piston, the valve, D, will
and that at B rising, the water will rush upward
flow out at the spout.

372. The pump we have described is called th
tion pump, because the water *appears* to be suck
into the vacuum made by expelling the air, thou
reality, this is not the case; but the water ris
cause there is an external, atmospheric pressure
is not balanced by any pressure within the pump

Fig. 68



373. The *forcing pump* c
of a barrel, A B, and a piston C
ed a *forcer*. There are two
one at D, and the other at S.
piston is solid, or without any
When the piston is pushed dow
is pressed out at the valve S,
sues from the branching pipe
vacuum being thus formed,
rises through the valve D, is p
upon by the piston and forced th
the branching pipe, V, from w
it issues in a *jet*. As the acti
pumping is unequal, it must pr
an unsteady current of water;
medy this, is an air vessel, U, into which is fi
small tube, T. By means of condensed air wh
confined in the air vessel, and which first receiv
force given by the piston, and then reacts upo
water, with nearly a uniform power, the water is
up the tube, T, in a steady stream.

374. The *Fire Engine* consists of two f
pumps, working into one air vessel placed be

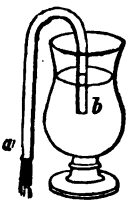
372. Why is this called the suction pump?—Does the wa
in the cylinder because it is sucked up into the vacuum?

373. Describe the forcing pump.—How is the action of thi
rendered nearly uniform?

374. What does the fire engine consist of?

them, and from which the spouting-pipe or *hose* for directing the water upon the fire proceeds.

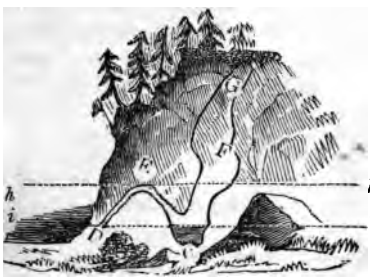
Fig. 69.



375. A *Syphon* is a bent tube, with one arm longer than the other. The syphon being filled with water, and the mouth of the shorter arm immersed in a vessel of liquid, as in the figure, the water will flow out of the longer arm by its own gravity, and thus leave a vacuum, in the syphon. The liquid from the vessel will rise in the shorter arm to fill this vacuum, and continue to flow off through the longer arm, until the vessel is emptied.

376. Intermitting springs are produced on a principle similar to the action of the syphon, the water flowing through natural crooked pipes or syphons, from reservoirs in the earth, which fill only at certain seasons.

Fig. 70.



377. Let G F C represent a cavern in a mountain, from the bottom of which, C, proceeds the irregular, syphon-like cavity, C E D. As this cavity fills by rain,

375. Describe and explain the action of the syphon?
376. How are intermitting springs produced?
377. Describe the figure.

snow, or little rivulets penetrating the pores of the ground, or interstices of the rocks, the water will gradually rise in the short arm, C E, of the syphon till it has reached the level, *h h*, when it will begin to flow through the longer arm, D E. As the water rises higher, or towards C, it will flow out at D with greater force; as soon as the water level sinks to *i i*, the air will rush into the syphon, and the water, thus impeded by the pressure of the air, will cease to flow.

378. Ignorant people have sometimes imagined the alternate flowing and stopping of intermitting springs to be the effect of magic; and impostors have pretended that they were gifted with power over such springs and that their sudden changes took place at their command. Superstition dwells with ignorance; the more mankind are enlightened, the more they understand that the changes which take place in the physical world, are the effects of the general laws established by God for the regulation of the universe. Even what seem to be irregularities, or exceptions, when traced to their causes, are found to result from these very laws.

CHAPTER XXIII.

Vapors—Gases.

379. The air of the atmosphere, though, in some respects, it resembles steam and other vapors, differs from them, in one important particular,—it is *perma*

---

378. Impressions made on the ignorant by the ebbing and flowing of springs.—Effect of enlightening the mind.

379. How does atmospheric air differ from steam?

nently elastic; that is, it cannot, by any degree of pressure, or of cold, be brought into a liquid or solid state. Steam, by losing a certain quantity of heat, becomes liquid, and by losing another quantity of heat, becomes solid. Though steam is highly elastic, the same particles in the form of water and ice are not elastic; therefore steam is not classed among the *permanently* elastic fluids.

380. Fogs, mist, and steam are all vapors consisting of particles of water, expanded in a greater or less degree by heat.

381. It is the great *elastic force* of steam which renders it so important as a mechanical agent.

382. The *Steam Engine* consists of a large cylinder or barrel, in which is fitted a solid piston like that of the forcing pump; a large boiler is attached, containing water, which being subjected to heat, is constantly passing off in steam; the steam forcing up the piston, opens a valve which admits cold water; this condenses the steam, which instantly loses its elastic force, and the piston falls; a new portion of steam from the boiler again raises the piston, and again the cold water, which it meets on passing the valve, chills and condenses it, and the piston falls. This action of the piston, moves up and down, a large horizontal beam, called the working beam, and this, by means of a crank which changes the direction of the force, turns the paddle-wheel that gives the steam boat its motion.

383. Here *steam* is the *force* employed to give *motion;*—steam moves the piston, the piston communicates its motion to the working beam, the working beam to the crank, and the crank to the wheel.

---

380. What are fogs, mist, and steam?

381. What renders steam important as a mechanical agent?

382. Describe the steam engine.—What produces motion in the steam engine?

383. How is motion transmitted in the steam engine?

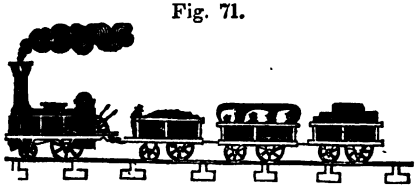
384. The steam engine is a wonderful invention; people who in former times believed in witchcraft, could never have imagined a more effective agent in the hand of the most powerful magician. It regulates its own motion, the supply of water to the boiler, the quantity of wood to the fire, and the amount of steam which is necessary; it opens and shuts its valves, oils its joints, and rings a bell to warn its keepers when any thing goes wrong.

385. It consumes no food which is needed by men or animals; it is fed with coal or wood, and requires this only when at work.

386. A steam engine possessing the power of several hundred horses, is yet perfectly manageable by one person.

387. Steam engines are not only used in navigation, but in manufactories of various kinds.

Fig. 71.



388. In the new and expeditious mode of travelling on rail roads, the steam engine moves a carriage which is called the *locomotive*;* this is followed by a *tender*, containing the engineer or driver, with a supply of fuel and water; carriages for passengers called *cars*, are attached, the train varying in number, according to the

* From *locus* a place, and *moveo* to move,—signifying to move from a place.

384. What are some of the operations of the steam engine?
385. What food does it require?
386. Is it easily managed?
387. For what are steam engines used?
388. How are rail-road carriages moved?

er of passengers and amount of goods to be con-
l.

Gases.

. Matter is often treated of under the three divi-
of *solids*, *liquids* and *gases*. Under the head of
are included atmospheric air and steam; but we
shown that steam differs from air in not being
anently elastic. Air seems very properly to be
guished from those gaseous bodies which exist
sparingly in nature, and are produced by chemical
tions.
). Air itself is composed of two gases called
en and nitrogen, and water of two gases called
ygen and nitrogen.
. All animal and vegetable substances, as well as
s, stones, and ores of metals are, in part, com-
l of gases, the study of which belongs to Chem-

CHAPTER XXIV.

General Summary of Pneumatics.

2. Air being a lighter substance than liquids or
s, is situated above them, or fills cavities which
ot filled with either solids or liquids.

Under what three divisions is matter often treated?—What
cluded under the head of gases?
Of what are air and water composed?
Do gases enter into the composition of most substances?—
hat science does the study of gases belong?
Comparative lightness of air.

393. The air which surrounds the globe, e about forty-five miles in height, is called th sphere; this is the element in which we live, a is as necessary to us as water is to fishes.

394. The atmosphere moves with the earth the sun. The lower portions are heavier t higher, because the pressure of the higher upon the lower, renders them more dense.

395. The higher regions of the air are *col* the lower; the latter receive warmth from the

396. We cannot *see* air because it is perfect parent; but we *feel* it on moving our hand through it; and we *hear* it in the sounds w upon the ear.

397. Air possesses the two essential qualitie ter, *extension* and *impenetrability.*

398. The air-pump is a machine for exhaus air from a glass receiver, in order to make ments in a vacuum.

399. The Condenser is a machine for maki riments with condensed air.

400. The *Barometer* or weather glass is a ment which shows the *pressure* of the *air.*

401. The *Thermometer* shows the degree in the air.

402. The *Hygrometer** measures the d

* From *urgos*, a Greek word signifying moisture, and measure.

393. Height of the atmosphere, and its importance.

394. Motion of the atmosphere.—Cause of the lowe being the heavier.

395. Why are the higher regions colder?

396. Do we *see* and *feel* air?—Do we *hear* it?

397. Does air possess the essential qualities of matter?

398. What is the air-pump?

399. What is the Condenser?

400. What is the Barometer?

401. What is the Thermometer?

402. What is the Hygrometer?—Why do harp s strings break in damp weather?

moisture in the air; all substances which contract in a moist atmosphere, or expand in a dry one, are hygrometers; but instruments are made so as to indicate with exactness the quantity of water in the atmosphere. A human hair properly prepared, is among the best of this kind; the hair becomes longer or shorter according to the quantity of moisture around it, and is made to move an index which points out the degrees. A clothes line which hangs loosely when dry, will, after a shower, appear to be drawn tightly. Harp and guitar strings often break in damp weather, from their becoming shorter, and therefore, being strained with a force greater than their cohesion.

403. Water rises in the suction pump by the force of atmospheric pressure. The weight of a column of the atmosphere cannot support a column of water more than 34 feet high, nor a column of mercury more than about 30 inches high.

404. The action of the syphon and of intermitting springs is caused by atmospheric pressure.

405. When the air moves swiftly it is called *wind*.

---

403. How high a column of water and of mercury will a column of the atmosphere balance?

404. What causes the action of the syphon and intermitting springs?

405. What is wind?

PART V.

ACOUSTICS,

OR THE SUBJECT OF SOUND.

CHAPTER XXV.

Sonorous Bodies.

The Ear.

406. *Acoustics* is the *science which treats of sound.*

407. Bodies which produce sound are called *sonorous* bodies.

408. Sound is caused by vibrations in the air, communicated to it by vibrations of the sounding body. When we hear the sound of a musical string, the ear receives from the air as many strokes, as the string performs vibrations in the same time.

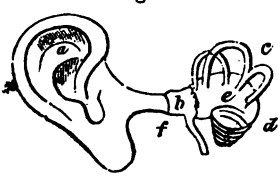
409. The ear is a most curious instrument, invented by the Creator for the purpose of hearing. Placed as

406. What is Acoustics?
407. What are sonorous bodies?
408. What causes sound?
409. Beauty of the human ear.

are the human ears on each side of the head, in a central point, from whence lines drawn diagonally from the eyes to the chin would meet, they add greatly to the symmetry of the head. Had our ears, instead of being placed as they now are, been inserted in our foreheads; had they been longer, like those of the ass, or mere cavities without the external cartilages and muscles, how dreadfully would the beauty of the human countenance have been marred! Every thing which God has made is just as it should be; while He has *one great object* in view, others of less importance are not overlooked. Thus, though the ear is designed for hearing, it is rendered also a graceful appendage to the human figure.

410. The great wonder with respect to the ear, is the arrangement of its internal parts, which are curiously fitted to collect and concentrate the waves of sound caused by the vibrations of sonorous bodies.

Fig. 72.



411. We perceive, on looking into the ear, a wide mouthed tube *a*. This is an ear-trumpet, its wide mouth serves to collect the waves of sound, which are concentrated at the bottom, or nervous part of the ear-tube. This tube, by the action of certain muscles in some animals, is moveable, so that it can be directed towards the point from whence sound proceeds.

---

410. What parts of the ear are most wonderful?

411. What do we first perceive on looking into the ear?—What is the drum of the ear, and what is its use?—What is the eustachian tube?—What is the effect of obstruction in this tube?—Where is the entrance into the labyrinth?—How is this entrance connected with the drum of the ear?—What is the labyrinth of the ear?—What is the use of the auditory nerve?—How is the vibration conveyed from the labyrinth to the auditory nerve?—What are the parts of the labyrinth?

The *tympanum*, or drum of the ear, *b*, is a tight-drawn membrane, situated at the bottom of the ear-tube, upon which the concentrated sound falls and causes its vibration. The air within the drum communicates with the external air by a passage, *f*, called the *eustachian* tube, which leads to the back of the mouth. When this tube is obstructed by wax, a degree of deafness is produced, and the cracking noise and return of acute hearing, which is often caused by sneezing or coughing, are effects of the removal of this obstruction.

At *e* is an oval door, or entrance into the labyrinth; this is connected with the drum of the ear by a chain of four small bones, which serve to convey to the labyrinth the vibration from the drum.

The labyrinth is that complex, inner compartment of the ear over which the nerve of hearing, or auditory nerve is spread as a lining. This nerve, like the optic nerve of the eye, is a connecting link between the organ of sense and the great *sensorium*, the brain. The labyrinth is filled with water, so that when the membrane of the drum, acting upon the chain of small bones, compresses the portion of water next this chain, the pressure is instantly felt throughout the whole mass of water, and thus the vibration is conveyed to the lining of the labyrinth, or the organ of hearing, which is also called the *auditory* nerve.

The labyrinth consists of the *vestibule* or oval door, *e*, the three semicircular canals, *c*, which are imbedded in the hard bone, and the *cochlea*, *d*, which is a winding cavity like a small shell. In this cavity are fibres stretched across like harp strings, these are called the *lyra*.

412. The waves of air which produce sound may be compared to the tremulous motion which agitates the smooth surface of water, when a stone is thrown into

412. To what may waves of sound be compared?

it; the waves or undulations become fainter as they are more distant from the centre of motion.

Fig. 73.

413. The figure represents waves of sound in the atmosphere; as they diverge from the point, A, it will be readily understood that they must become weaker, in the same manner that rays of light become fainter, as they are more diffused. The points *a b c d e f* with the intermediate spaces represent undulations of air, spreading in concentric circles like waves, in a still lake when disturbed. Each particle of air, on receiving an impulse, either directly from the sonorous body, or by transmission, becomes agitated, moves back and forth like a vibrating pendulum within a limited space, and at length ceases to move; but it has communicated motion to contiguous particles, which, in their turn, vibrate and communicate motion. On account of the extreme rarity and elasticity of air, vibration of sound extends to a much greater distance than the circular waves of water. The undulations of air being within a sphere extending upwards and downwards, as well as outwards, while those of water extend only upon a horizontal plane.

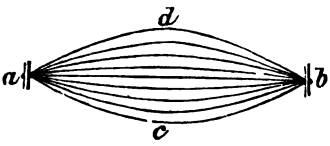
414. The music of the piano, harp and guitar is produced by the vibration of *elastic strings*. No string will vibrate unless it be elastic.

---

413. Describe the figure.—How is each particle of air affected on receiving an impulse from a sonorous body?—Why do vibrations of sound extend farther than the circular waves of water?

414. What musical instruments produce sound by means of elastic strings?

Fig. 74.



415. Suppose *a b* to be an elastic string fastened at the two ends; on drawing this string towards *c*, and then letting it go, it springs back to its straight position, but having acquired a momentum like that of a vibrating pendulum, instead of resting here, it passes on towards *d*, nearly as far in the opposite direction. This is *one vibration;* the momentum then acquired produces other vibrations, each less than the former, until the resistance of the air and the friction of the string overcome the velocity, and the string rests in the original position *a b*.

416. Sound is produced by these vibrations in this manner; the string strikes against the particles of air which are contiguous to it, these particles being condensed by the pressure and impelled forward, agitate the surrounding atmosphere; each agitation affects the contiguous parts, until the whole mass, within a certain distance, assumes a tremulous motion. Thus sound does not proceed from a progressive portion of air, but from a series of contractions and expansions of this fluid.

---

415. Describe the figure.
416. How is sound produced by the vibrations of strings?

CHAPTER XXVI.

Medium of Sound—Echo—Velocity of Sound.

Medium of Sound.

417. A bell struck under an exhausted receiver emits no sound, while in condensed air it rings loud and clear. On high mountains, where the air is light, sound is feeble; but in caverns and mines where the air is more dense, sounds are remarkably clear and distinct.

418. Liquids and solids convey sounds with greater velocity than air. Experiments have shown that sound is conducted by water, 4,709 feet in a second, while its velocity through air is estimated only at 1,142 feet in a second.

419. The ear must be in contact with one portion of the liquid or solid body, while the vibration is caused among the particles of the same body in another part. If, while you apply your ear to one end of a log, a person scratches with a pin at the other end, the sound will appear very loud. The American Indians understand that solid bodies, even the earth itself, convey sound with great facility. When these wild and artful people suspect that enemies are approaching, they apply their ears close to the ground, in order to discover

---

417. How is it proved that air is the medium of sound?

418. What bodies besides air convey sound?

419. What is necessary in order that sound may be conveyed to the ear by a solid or liquid?—How do the Indians discover footsteps at a great distance?

the noises made by the footsteps of their foes, w
too far off for the sounds to be conveyed thro
the air.

420. It appears that iron and glass are among
best conductors of sound, transmitting it at the rate
17,500 feet, or more than three miles in a second.

421. But the *air* is the *principal medium of sound*
it is around us on every side, ready to bear the me
sages which we may intrust to it. Should the a
cease to perform its office, the lips might vainly attempt
to communicate thoughts and feelings; we might see a
motion of the lips, but we should hear no voice. Air
alone can convey *articulate sounds*, therefore, it is
often spoken of as the *only medium* of sound.

Echo.

422. The ancients, among the imaginary beings with
which they peopled the heavens, the seas, and the
earth, represented Echo as a wood nymph, who had so
pined away for love that nothing but her voice was left
her. Thus one of the poets says,

> "A nymph she *was*, though only *now* a *sound*,
> Yet of her tongue no other use was found,
> Than now she has; which never could be more
> Than to repeat what she had heard before."

423. You have all doubtless heard Echo repeat
sounds. When you have called loudly the name o
one of your companions, you have been mimicked b
Echo; when you have spoken several words, the la
word, or a few of the last syllables have been repeate
from some distant hill or mountain, by Echo. Her
again, it was natural that the ignorant should tremb
with superstitious fear of some enchantment or u

420. Do iron and glass conduct sound?
421. Can articulate sounds be made without the medium of air
422. How did the ancients represent Echo?
423. What is done by Echo?

ırthly power. But the cause of this phenomenon is ery simple, and easy to be understood.

424. When you throw your ball against a rock or ıe side of a building and it rebounds, you do not ıink this wonderful; now an echo proceeds from a ıuse similar to that of the rebounding of a ball. The brations of air meet with some wall of a building, ome hill or mountain, at a little distance, and being re-flled by such obstacle, rebound from it, or are reflected ıck, like the ball; and as you may catch the rebound-ıg *ball* with your hands, so your ear catches the *verberating sound.*

425. Sounds uttered by one standing in front of a ıilding, at a certain distance, will be returned in a ght line, and the Echo may be heard by the person eaking; but let the person uttering the sound, stand that the vibrations fall upon the wall obliquely, he ill not hear the echo, though another, standing as far ı the opposite side, would hear it; thus one person anding at the side of a mirror, sees the image of ıother person standing on the opposite side, though does not see his own image.

426. As a vibration of sound rebounds according to e same law as a wave of water, or an elastic ball, in der that an echo may be perfect, the surface produc-g it must be smooth, and of some regular form.

The various articles of furniture in a room, especially ose of a soft texture, as carpets and curtains, act ıfavorably upon the vibrations which produce sounds. he labor of speaking audibly in a crowded room, is eater than in a room which contains few persons. ıy one who tries the effect of speaking or singing

---

424. What causes an Echo?

425. How is sound reflected?—In what case will not an echo be ard by a person who uttered the original sound, while it may be ard by another?

426. What is necessary to a perfect echo?—Causes which ope-e unfavorably for the vibrations of sound.

in an empty room, will be sensible that the power of sound is much heightened by the vibrations of bare walls.

Velocity of Sound.

427. Sound moves at the rate of nearly a quarter of a mile in a second. Light moves with greater velocity than sound; we see the flash, before we hear the report of a gun—we see the lightning before we hear the thunder. When a storm is very distant, many seconds will pass after the lightning, before the thunder; and when we have first seen the flash, we have no reason to fear the thunder which will follow it, because, if the cloud from which it issued, were directly over head, the flash and report would have appeared at the same instant.

---

427. At what rate does sound move?—Which moves with the greatest velocity, sound or light?—Why do we not usually have thunder at the same instant that we see the lightning?

PART VI.

OPTICS,

OR THE SUBJECT OF LIGHT.

CHAPTER XXVII.

Definitions—Diffusion of Light—Reflection and Refraction—Angles of Incidence and Reflection.

428. As air is the medium by which sounds are conveyed, light is the messenger that reveals to the eye the forms and colors of distant objects. *Without air*, we could not *hear*,* without *light* we could not *see*.

429. *Luminous* bodies are those which shine;—the sun shines by its own light; the moon shines by light which she receives from the sun. The light of the moon is called *reflected* light.

430. *Transparent bodies* permit light to pass through them. Window-glass is transparent;—we can see through it.

* Solids and liquids do indeed convey sounds, but air is the general medium, and without its aid, sound would cease to be a source of delight, or even of utility.

428. What enables us to see distant objects?

429. What are luminous bodies?—How does the light of the moon differ from that of the sun?

430. What are transparent bodies?

431. *Opaque bodies* permit no light to pass through them; some opaque bodies *reflect light;* a piece of polished tin reflects powerfully. A glass mirror is rendered opaque by the metallic coating which is laid on one of its sides, so that light instead of showing through it, is *reflected.* The window-glass does not show us our image, but shows us to those who may be on the other side of the window; a glass mirror reflects our image to ourselves, while it screens us from the sight of those who may be behind it.

432. Light moves in *straight* lines; we can see objects through a straight tube, but not through a bent one; though we can hear through a bent tube. It is because light moves in straight lines, that, when standing in a line with a row of trees of similar height, the nearest tree conceals the others from view.

433. The light diffused by a luminous body becomes fainter with increasing distance. Thus, suppose *a* to be a luminous body radiating light in all directions; now as the same proportion of light illumines the space within the circle *c b*, as in the circle *c d*, it is evident that *c b*, must be more strongly illuminated. At *d*, which is twice the distance of *b*, from the candle, the intensity of light is four times less, than at *b*; at three times the distance, it would be nine times less; at four times the distance, it would be sixteen times less, and so on; *for diverging rays of light diminish in intensity as the squares of the distance increase.*

Fig. 75.

---

431. What are opaque bodies?—What renders a glass mirror opaque?—In what respect does the window glass differ from the glass mirror?

432. In what lines does light move?

433. Why does light become fainter with increasing distance *from a luminous body?*

Of Reflection and Refraction.

434. The term *reflection*, as used in optics, signifies the rebounding of light from surfaces on which it falls. But all bodies do not reflect light; it is only polished surfaces which have this property; and of such surfaces, some, as diamonds and glass, may transmit, without reflecting light. *Mirrors* or looking-glasses derive from reflection, their property of throwing back the image of an object.

435. *Refraction** denotes the bending of the rays of light, as they pass from the surface of one transparent medium to another. Thus, in passing from air into glass, all the rays, except those that fall perpendicularly, are turned from their straight course, or, as it is expressed in optics, they are *refracted.*

436. To the refraction of light, we are indebted for the power of the *lenses* or magnifying glasses, which are used in the manufacture of spectacles, telescopes, and microscopes. It is indeed to the refraction of light, as it passes through the different lenses of the eye, that this organ owes its power of seeing.

Angles of Incidence and Reflection.

437. A ray of light turned back into the same medium in which it moved before its return, is said to be reflected.

438. Incident† rays are those which fall on the surface of a body; reflected rays are those which are thrown from it.

---

* From the Latin prefix, *re*, and *frango* to *break.*

† From the Latin *incido*, to fall upon.

---

434. What is meant by the reflection of light?—What bodies possess this property?

435. What is meant by the refraction of light?

436. What are some of the advantages derived from the refraction of light?

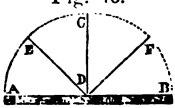
437. When is a ray of light said to be reflected?

438. What are incident rays?

439. When a ray of light falls perpendicularly on an opaque body, it is reflected back in the same line in which it proceeded; in this case, the *reflected ray returns* in the same path as that in which the *incident ray went*. But when a ray falls obliquely, it is reflected obliquely; that is, the reflected ray proceeds in a direction on the opposite side, as far from the perpendicular, as was the incident ray.

440. The angle made by the incident ray at the surface of the reflector with a line perpendicular to that surface, is called the *angle of incidence;* the angle made by the reflected ray with the same perpendicular line, is called the *angle of reflection.*

Fig. 76.



441. Suppose A B to represent a reflecting surface, C D a perpendicular to this surface, E D the *incident* and D F the *reflected* ray, the angle E D C is the angle of incidence, and the angle F D C is the angle of reflection.

The angles of incidence and reflection are equal. Let a circle be described around the point D as a centre, (see the preceding figure) taking D E for a radius, and it will be found that equal portions of circumference lie between E C and C F; this proves that the angles E D C and F D C are equal. And again, since A D C is a quadrant equally divided by the line E D, and B D C is a quadrant equally divided by F D, it follows that the angle A D E is equal to B D F, and the angle E D C has been shown to be equal to F D C.

---

439. What happens when a ray of light falls perpendicularly upon an opaque body?—When a ray falls obliquely?

440. What is the angle of incidence?—What is the angle of reflection?

441. How does the figure illustrate the manner in which light is reflected?—How is it proved by the figure, that the angles of incidence and reflection are equal?

Reflection makes objects visible.

442. It is by the reflection of light that objects are made visible; but light itself is invisible. If you close a room so that it is dark, except as a beam of light entering through a hole in the window shutter gives a partial illumination, you may see a bright spot on the wall opposite, and may trace the course of the rays of light by means of the motes or small particles of dust floating in the air. Thus the agent, which enables us to see all other things, remains itself unseen, and, like its great Creator, is known to us only by its effects.

CHAPTER XXVIII.

Mirrors.

443. *A mirror* is a smooth surface which reflects light. Thus a still lake, a polished plate of metal, and a looking glass are mirrors.

444. Mirrors are of *three* kinds, the *plane*, *convex*, and *concave*.

445. A *plane mirror* is flat, or has its surface a perfect plane, as in a common looking-glass.

446. A *convex mirror* is globular, and reflects images from a rounded surface.

447. A *concave mirror* is curved inward, and reflects light from a hollow surface.

---

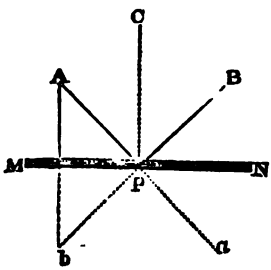
442. How are objects made visible?—Is light itself visible?
443. What is a mirror?
444. How many kinds of mirrors are th[ere]
445. What is a plane mirror?
446. What is a convex mirror?
447. What is a concave mir[ror]

The Plane Mirror.

448. A common looking-glass is a *plane mirror*, composed of glass rendered opaque, by a coating of *tin* and *mercury*. Thus, after the rays of light have passed through the glass, they are thrown back by the metallic surface.

449. Rays of light are reflected from a plane mirror at the same angle at which they strike its surface. Two persons may stand in such positions that each can see the image of the other in a mirror, without seeing his own. Thus, suppose M N to represent a mirror, A and B the position of two persons with regard to it; the dotted line P C is a perpendicular drawn from the surface of the glass at the point P, where the rays from A, B fall upon the mirror. The person at A, looking toward the mirror, would not see his own image, but that of him who stood at B, which would appear at *b*, as far behind the mirror, as B is actually before it; in the same manner, B would see A as if standing at *a*. Thus the image of a person may be seen by reflection from a mirror, when the individual is not conscious of being observed.

Fig. 77.



450. *A person may see the whole of his figure in a plane mirror which is but half his height.*

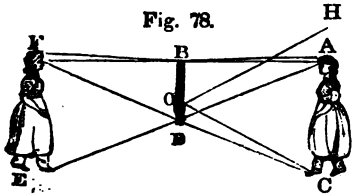
---

448. What is a common looking-glass?—Why is it not transparent?

449. What is said of the reflection of light from a plane mirror? Explain the figure.

450. Why is it that a person can see the whole of his figure in a plane mirror which is but half his height? Suppose the mirror be *less than half* the height of the figure.

Fig. 78.



Suppose B D to be a mirror half as high as the figure at A C; the ray of light, A B, from the eye, falling perpendicularly on the mirror is reflected back in the same line; but the ray, C D, from the foot, which falls obliquely, is reflected in the line D A. Since we view objects in the direction of the reflected rays which meet the eye, and as the image appears at the same distance behind the mirror that the real object is before it, the line A D must be extended to E, and the line C D to F, and here the image will appear to be situated.

But if the mirror be *less than half the height of the figure*, the whole of it cannot be reflected. Thus it may be seen in the preceding cut, that were the mirror only the height of O B, the line C O from the foot of the figure would be reflected in the line O H, above the eye.

Convex Mirrors.

Fig. 79.

451. Convex mirrors reflect light from a rounded surface, as A B. Any polished convex body is a mirror, as the spherical part of brass andirons, with which children often amuse themselves in viewing their own miniature likenesses.

452. The human eye is the most perfect of all convex mirrors; so great is it power of diminishing objects

451. What kind of surface has a convex mirror?

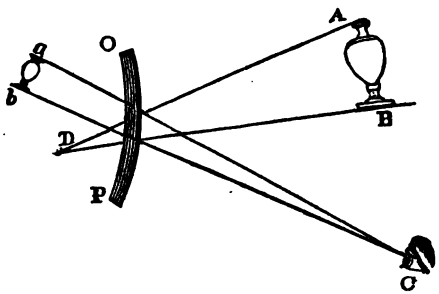
452. What is the most perfect of all convex mirrors?—What is said of the power of the eye to diminish objects, and yet preserve their likenesses?

and yet preserving their exact likeness, that on a surface of less than half an inch in diameter, may be represented a landscape where men, animals and buildings, distant fields and hills, mountains and clouds, are distinctly delineated.

453. Convex mirrors *disperse rays of light*, causing *parallel rays to diverge, diverging rays to diverge more, and converging rays to diverge less.*

It is owing to this *divergence* or spreading of the reflected rays, that objects appear smaller when viewed in a convex mirror, than they are in reality.

Fig. 80.



454. Let the vase, A, B, be placed before the convex mirror O, P, an eye at C, would see its miniature image at *a b*. Had the incident rays from A, B, the extremities of the vase, met with no interruption, they would have converged at D, but being reflected from the convex surface, they do not converge until they

---

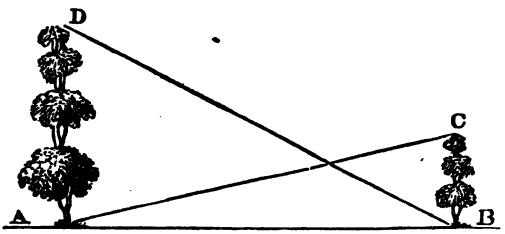
453. What effect have convex mirrors in changing the relative position of the rays of light which they reflect?—Why do objects appear smaller when viewed in a convex mirror?

454. Explain the figure.—Why does the image appear smaller than the object?

reach the point C, more distant from the mirror than D. *The image, on account of the divergence of the rays being seen under a smaller angle than the object, appears smaller.*

455. Objects appear large or small according to the breadth of the angle formed by rays of light from their extremities. In looking upon a large and a small tree at equal distances from the eye, the angles made by the rays of light from the two upper and lower extremities, give the idea of their comparative height, for the wider the opening of the angle as it recedes from the eye, the larger the object appears. Thus the angle

Fig. 81.



A B D, being greater than the angle B A C, the object A D appears proportionably larger than *C B.* It is the diminishing of the *visual* angle by causing rays of light to be farther extended before they meet the eye which produces the miniature images of convex mirrors.

---

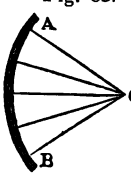
455. How does the figure prove that objects appear large or small according to the breadth of the angle formed by rays of light at their extreme parts?

Concave Mirrors.

Fig. 82.

456. Concave mirrors reflect light from a *hollow surface.* The concave mirror being in form, the reverse of the convex, we find its powers essentially different. *Concave* mirrors collect rays of light and *magnify* objects, while *convex* mirrors *disperse* rays of light and *diminish* objects, and plane mirrors reflect rays of light, without either enlarging or diminishing the visual angle, and, consequently, represent objects of their natural size.

Fig. 83.



457. In a concave spherical mirror, rays *radiate* from the centre in all directions, and will, therefore, be reflected back upon the central point. Thus if A B were a concave spherical mirror, of which C were the centre, rays issuing from C, would strike perpendicularly upon the concave mirror, and be reflected back to the same point.

458. The *sun's rays*, on account of the vast distance of that body from the earth, are considered as parallel; they converge to a point at the focus of parallel rays in concave reflectors. The word *focus* originally signified the burning point, or fire-place.

459. The greater the concave surface, and the more perfect the reflecting surface, the more powerful will be the effect of the mirror in concentrating the solar rays.

---

456. How do concave mirrors differ from convex mirrors?

457. Explain the figure.

458. Are the sun's rays parallel?—Where are they converged to a point?—What was the original meaning of the word focus?

459. On what two circumstances does the power of a concave reflector depend?—Of what size have metallic concave mirrors been made?—What is said of the heat of the focus of such mirrors?

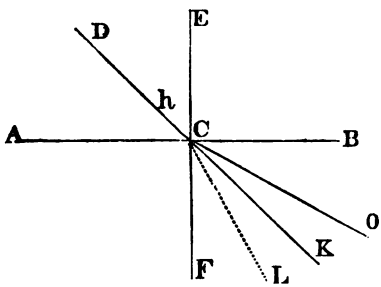
Metallic concave mirrors have been manufactured four or five feet in diameter; they are called *burning mirrors.* The heat at the focus of such mirrors is sufficiently powerful to fuse metals, and even earths.

CHAPTER XXIX.

Refraction of Light.

460. Having considered the various ways in which light is *reflected* by opaque bodies, plane, convex and concave, we now pass to the subject of *refraction,* or a consideration of the manner in which light passes through transparent bodies.

Fig. 84.



461. A ray of light, E C, falling through air perpendicularly, upon a surface of glass or water, A B, passes on in a straight line through the body to F; *but*

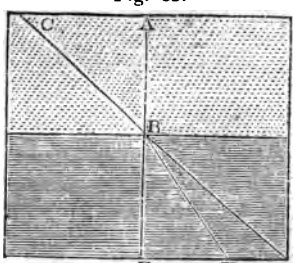
460. What subject is now to be considered?

461. Suppose a ray of light fall perpendicularly upon a surface of glass or water.—Suppose it fall obliquely.

if a ray in passing from one medium into anoth different density, fall obliquely, as **D h**, *it is bent its straight course, which would be in the directi* **K**, *and recedes from it, either towards* **L** *or* **O**, (ac ing to circumstances which we shall soon expl *and this bending is called refraction.*

462. If light pass from a *rarer* into a *denser med* it is *refracted towards a perpendicular* in that med

Fig. 85.



Suppose the ray **C**] pass obliquely from *air* a *denser* medium, viz. ter. The course of ray through the air w be in the direction **C**] but as soon as it enters water it is bent towards perpendicular, **A B E**, moves on towards **F**, i direction between **B D B E**, making a *less a* with the perpendicular, than if it had suffered no fraction.

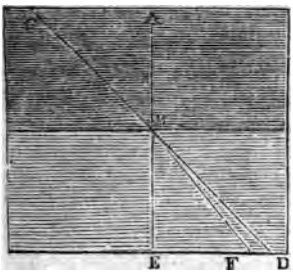
463. If light pass from a *denser* into a *rarer dium*, it is refracted farther from a perpendicula that medium. Let the upper and more shaded

---

462. How is light refracted when it passes from a rarer i denser medium ?—Explain the figure, illustrating that propos

463. How is light refracted when it passes from a denser i rarer medium ?—Explain the figure.

Fig. 86.



of the figure represent glass, and the lower part a *rarer medium*, viz., water; and let C B, be a ray passing obliquely from the glass into water; on arriving at the surface of the rarer medium, the ray does not pass on in a straight line towards F, but is bent from the perpendicular B E, in the line B D, making a *greater angle* with the perpendicular, than if it had suffered no refraction.

464. Transparent bodies differ in their power of bending light:—as a general rule, the refractive power is proportioned to the density. Thus the refractive power of water is greater than that of air; the refractive power of glass is greater than that of water, and the refractive power of the diamond is greater than all.

Examples of Refraction.

465. An oar with one end in the water appears bent, and also somewhat shorter than it really is. The rays of light from the immersed part of the oar, proceeding from a denser to a rarer medium, are refracted *from* the perpendicular, and are inclined towards the eye of the spectator. Let *o m a* represent an oar, the part *m o* being out of the water, and the part *m a* in the water; the rays diverging from *a* will appear to diverge from *b*, nearer to the surface of

Fig. 87.

464. What is the general rule with respect to the refractive power of bodies?

465. Why does an oar appear bent in water?—Explain the figure.

the water; every point in *m a* will seem n surface than it is in reality, and the part c *m a* will appear bent, or to make an ang part *m o*.

466. The bottom of a river when viewed appears nearer to the eye than it is, in realit reason the water does not seem as deep as it i in bathing, are sometimes thus deceived, and lives in consequence of venturing in wate their depth.

467. When we look from a boat perpendi into the water of a river, we see the bottom in place, because there is no refraction. But th obliquely we view an object seen through a trans medium, the more its position seems changed.

468. A goldfish in a glass globe filled with may appear as two fishes, being seen by light through the surface of the water, and by straight pendicular rays passing through the sides of the g

469. The atmosphere is a transparent body, bec ing more dense in proportion as it is nearer the surf of the earth; *and the different strata of air, havi different degrees of density, vary in their refract powers.* It is supposed, that beyond the atmosph which surrounds our globe, there is, if not a vacuum medium of a highly rarified nature which is cal *ether*. The refractive power of the air is theref greatest at the earth's surface, and diminishes upwar

470. The heavenly bodies appear higher above

---

466. Why are we sometimes deceived as to the depth of wat

467. In what case do we see the bottom of a river in its situation?

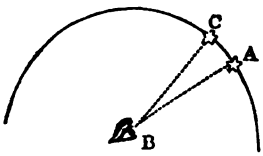
468. Why does a goldfish seen through water, in a glass gl ometimes appear like two fishes?

469. Why does the atmosphere vary in its power of refracti There is this power greatest?

470. Why do the heavenly bodies appear higher above the on than they are?

horizon than they really are, because the rays of light, instead of moving through the atmosphere in straight lines, are continually bent towards the earth in consequence of meeting with different mediums, which become denser as they are nearer the earth.

Fig. 88.



471. The figure represents the difference in the *real* and *apparent* situation of the star, A. Rays of light falling obliquely on the earth would be refracted in a curve, as in the line A B; but the star would be seen in the direction of a tangent to that part of the curve which meets the eye B C; thus the *apparent* altitude is C B, while the *real* altitude is A B.

472. The distance between A and C is called the *parallax*, and is of great importance to astronomical calculations.

473. It is owing to their parallax that the moon and stars appear above the horizon before they have actually risen, and are seen after they have set. The day is also lengthened from this cause; for while the sun is yet below the horizon, he is visible by means of his refractive rays, and his light lingers some moments after he has sunk beneath the western horizon.

---

471. Explain the figure.—Which is the apparent, and which the real altitude of the star?

472. What is meant by the parallax of a star?

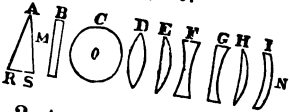
473. What effect has the parallax of the heavenly bodies with respect to the inhabitants of the earth?

CHAPTER XXX.

Lenses—The Eye.

474. The substance most used for refracting the r of the light in optical experiments, and for optical struments, is glass in various forms, the most comm of which are here represented.

Fig. 89.



475. An *optical prism* A, is a solid, having tw plane surfaces, A R, A S, inclined to one another; these are called its *refracting surfaces.*

2. A *plane glass*, B, has two plane surfaces parallel to each other.

3. A *sphere* or spherical lens, C, has every point in its surface equally distant from a common centre, *o.*

4. A *double convex lens*, D, is bounded by two *convex* or spherical surfaces, whose centres are on opposite sides of the lens.

5. A *plano-convex lens*, E, is bounded by a plane surface on one side, and by a convex one on the other.

6. A *double concave lens*, F, is bounded by concave surfaces on both sides.

7. A *plano-concave lens*, G, is bounded by a plane surface on one side, and a concave on the other.

---

474. What substance is most used for optical instruments?

475. What is an optical prism?—What is a plane glass?—What is a spherical lens?—Describe the double convex lens.—Describe the plano-convex lens.—Describe the double concave lens.—Describe the plano-concave lens.—What is a meniscus?—Describe the concavo-convex lens.

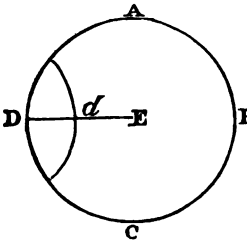
8. A *menis-cus*, H, is bounded by a concave and a convex spherical surface; and these two surfaces meet if continued.

9. A *concavo-convex lens*, I, is bounded by a *concave* and a *convex* surface; but these two surfaces do not meet though continued.

476. A *lens** is usually made of glass, ground into such a form as to collect or disperse the rays of light which pass through it.

477. A convex lens collects rays of light. A concave lens disperses rays of light.

Fig. 90.



478. The *sphere* of a lens is an imaginary circle, of which its surface is a portion. Thus the circle A B C, is the sphere of the convex lens, D.

The *radius* of a lens is the radius of its sphere, as D E; and a line D *d*, passing through its centre, is its *axis*.

479. The *focus* is that point beyond the convex lens where the refracted rays meet. This point depends upon the form of the lens and the refracting power of the substance of which it is composed. The less convex or bulging the lens is, the more nearly it approaches a plane glass, and consequently the more distant is its focus. The more convex or bulging a lens is, the nearer is its focus, because the more obliquely will the rays, at any

* So called from the Latin *lentil*, a bean, on account of its shape.

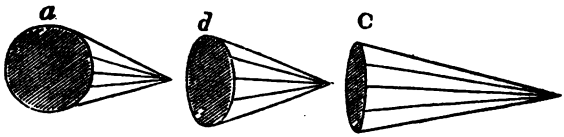
476. How is a lens usually made?

477. What are the different effects of a concave and a convex lens upon rays of light?

478. What is the sphere of a lens?—What is the radius of a lens?—What its axis?

479. What is the focus of a lens?—In what case is the focus more distant from the lens?—In what case is the focus shorter?

Fig. 91.



distance from the centre, fall upon the surface; and the sooner, in consequence of their being more bent, will they meet the axis. Thus *a*, which is a sphere, would converge the rays sooner than *d*, and the latter would converge them sooner than the less convex lens, C.

The Eye.

480. The eye, by turns a microscope and a telescope, is adapted to the purpose of viewing things near, or of extending its field of vision to far distant objects. On examining the structure of the eye, we find it a beautiful *optical instrument*, made in strict conformity to the laws of science, and perfectly fitted to be acted upon by light, so as to form an image of the objects from which light is reflected.

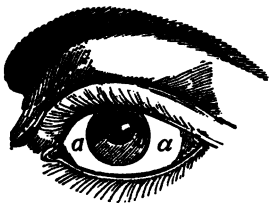
481. When viewed superficially, it consists of the *white*, the *iris*, and *pupil;* but by means of anatomical dissection various other parts have been discovered.

---

480. For what two very different purposes is the eye fitted?—In what respect may the eye be called an optical instrument?

481. What three parts appear when the eye is viewed superficially?

Fig. 92.

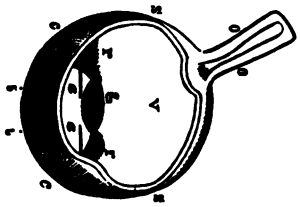


482. The figure exhibits a front view of the eye. The white part surrounding the centre is called the *sclerotic** coat, *a a*, and is continued within the orbit, round the back part of the eye-ball, being formed of a dense membrane, which includes, as in a bag, the other parts of the eye. It is perfectly opaque, and therefore is not continued over the front of the eye, but joins the transparent *cornea*,† *b b*, which differs from it chiefly in being completely *transparent*, and therefore serves the purpose of a window to admit light to the interior of the eye for the formation of images. Included within the cornea is the *iris*,‡ a sort of colored fringe, usually either of a dark brown or of a grayish blue tint; and hence the distinction between black eyes, and blue, or gray eyes. In the centre of the eye, surrounded by the *iris*, is a dark circular space of variable dimensions, called the *pupil*, through which the rays of light pass into the chambers of the eye.

* From the Greek, *skleros*, hard.
† From the Latin, *corneus*, horny.
‡ So called because it has many colors, like the rainbow, or *Iris*.

482. What is the sclerotic coat of the eye?—How does the transparent cornea differ from the sclerotic coat?—What is the iris, and what is its use?—What is the pupil of the eye, and what is its use?

Fig. 93.



483. The eye has *four coats* or *membranes*, viz the *sclerotic*, the *cornea* the *choroid*, and the *retina*. It has *two humors*, viz. the *aqueous* and *vitreous*; and *one lens*, viz. the *crystalline*. The figure represents a perspective view, and horizontal section of the left eye. The eyeball is nearly globular, and about an inch in diameter; *s s* represents the *sclerotic* coat, or white of the eye; *c c*, the *cornea*; *a a*, the aqueous humor; *i i*, the *iris*; g, the *crystalline lens*; V, the vitreous humor; *r r*, the *retina*; and *o o*, the *optic nerve*.

484. The eyes are situated in basin-shaped cavities in the skull, called the *orbits*; and there are various muscles attached to the ball of the eye, and to different parts of each orbit, which, by their contraction, give a certain degree of lateral rolling motion to the eyes, and thus assist in directing the sight towards different objects.

485. Eye-lids also, moved by muscles and fringed by eye-lashes, serve to guard the eyes from dust, and to screen, or shut them altogether from the access of too intense a light; and there are glands for the secretion of fluid to moisten the cornea, and by the motion of the eye-lids, keep its surface clear, and in a state adapted to yield perfect vision.*

* Moffat's "Book of Science," London, 2nd. Ed. p. 394.

483. How many membranes has the eye?—How many humors?—How many lenses?—Describe the figure.
484. How are the eyes situated, and how moved?
485. Of what use are the eye-lids?

CHAPTER XXXI.

Light and Shade—Imperfection of Vision—Optical Instruments.

Light and Shade.

486. The apparent distance and magnitude of objects in a landscape or picture, depend, in some measure, on *distinctness of outline, and brightness of color; or intensity of light and shade.*

487. Every one, in the least familiar with the effects produced on a picture by the use of colors, knows that distant views must be represented by faint shades and with indistinct outlines. By deepening the shadows, or heightening the colors of a distant mountain, it seems at once brought nearer to view, and the effect of distance is destroyed. Experience has thus taught us to associate the idea of distance with faintness of coloring.

488. Light radiating from a centre, becomes rapidly weaker as the distance from the centre increases. In looking upon a landscape illuminated by the sun, we see near objects, such as flowers, fruit and foliage, distinct in outline and glowing with bright hues. Strong lights and dark shadows prevail here. As the eye extends its range of vision, small objects are no longer visible; there is a blendiug of colors and of forms, until,

---

486. On what do the apparent distance and magnitude of objects in some measure depend?

487. How are distant views represented in a picture?

488. Appearance of a landscape illuminated by the sun.—Effect of distance upon lights and shadows.

at last, the outline of the distant mountain or ocean fades away into the blue sky.

489. The effect of increased or diminished light in making objects appear near or remote, must be obvious to any one who reflects a moment upon the subject. When a fire breaks out in the night, it appears to the spectator at a distance, as if it were very near; and he often, for this reason, feels needlessly alarmed for the safety of his own dwelling. The bright, red glare reflected from surrounding objects brings them nearer to his eye, and he sees the firemen with their engines, and people running to and fro, with all the bustle of the frightful scene, as if almost before his own door.

490. The seaman beholding distant mountains suddenly illumined with a bright sun, deems himself near to the land; again the sun is obscured, and the coast seems to have receded from him.

491. Objects appear larger, when seen through a foggy or misty atmosphere. This is owing to the diminished intensity of light, which makes them appear more distant without diminishing the visual angle subtended by them; for, to the man at forty rods distance, who subtends the same angle as the one at twenty rods distance, the same object must appear twice as large.

492. Thus, in the dim twilight, or misty atmosphere of night, objects seem magnified; and the superstitious, heightening this illusion by terror, readily convert a guide-board into a ghost; passing a church-yard

---

489. Why does a conflagration seen in the night appear to be nearer than it is?

490. How may the seaman be deceived in estimating his distance from land?

491. How do objects appear when seen through a misty atmosphere?—To what cause is this owing?

492. Why are strange sights seen in the night more than in the day?—What often gives rise to stories of ghosts, and wonderful *sights*?

in the night, when the atmosphere is charged with vapors, fear may readily combine with the optical deception produced by such an atmosphere, and cause the white monuments to appear like colossal spectres, and the sapling willow, with its pensile branches waving in the breeze, to seem like a huge giant tossing his arms to and fro.

Many a ghost-story has arisen from appearances which the ignorant have deemed supernatural. Strange lights, which, as they supposed, warned them of some coming event, might, by a knowledge of the laws of optical reflection, have been traced to their origin. Perhaps a candle at a neighboring window, or in the range of a mirror, which, itself unseen, reflected the light upon a wall, might have been the cause of their terror.

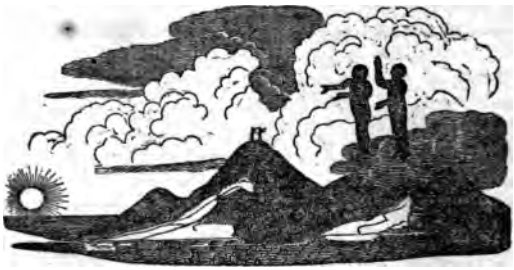
493. The inhabitants of the Hartz Mountains in Germany, had many legends of the *Spectre of the Brocken.** This was a gigantic figure which had often been seen walking on a certain ridge of the mountain, just at sunrise. A philosopher, who had learned that the wonder of *magic* may be traced to the operations of nature, went with a friend to the opposite ridge, to watch this phenomenon. Many mornings passed, and the Spectre had not made his appearance. At length, as the horizontal rays of the sun fell in a dense fog that hovered over the valley beyond, the *Spectre of the Brocken* was seen. But he was now in company with another spectre of equally gigantic dimensions; and the two very uncivilly mimicked every motion and

* The Brocken is a high range of mountains in Germany, remarkable as being "the seat of the marvellous."

493. What was the spectre of the Brocken, as it appeared to the inhabitants of the Hartz Mountains?—At what time in the day did the philosopher, who went to see the spectre, behold it?—Was it alone?—How were these appearances explained?

attitude of the philosopher and his friend; when they ran, the Spectres ran, and when they stood still, the Spectres were motionless. The philosopher explained

Fig. 94.



it all, by saying that these figures were merely *shadows* of himself and friend, *formed by their intercepting the rays of the rising sun, which illumined the mist atmosphere on the opposite ridge of the mountain* The apparent monstrous size of the figures, was owing to an optical illusion arising from the faintness of the shadows, which had the effect of making them appear distant, and consequently larger.

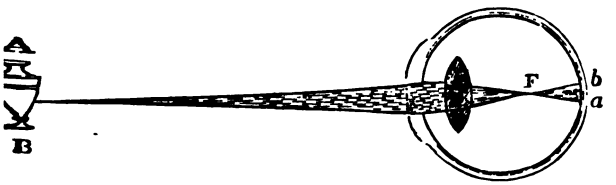
Imperfection of Vision.

494. Short-sightedness arises from a too great convexity of the crystalline lens. In such a case, the ray of light are converged so much, that they are brought to a focus before reaching the retina. Let D represent

---

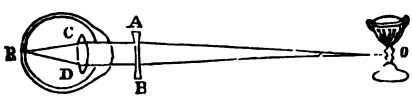
494. What is the cause of short-sightedness?—Explain the figure.—Why do short-sighted persons bring the objects viewed very near the eye?

Fig. 95.



the crystalline lens of the eye, with the pencils of light from A B falling upon it. These pencils are collected in a focus at F; from this point, the rays proceed in a diverging manner, and form at the retina, *a b*, a confused image. By bringing the object viewed *near to the eye*, as is done by short-sighted persons, the rays fall upon the eye more diverging, and are not so soon converged by the crystalline lens, so that the focus will fall upon the retina.

Fig. 96.



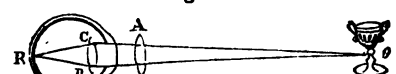
495. Short sighted people are assisted by concave lenses; the effect of which is to converge rays of light. Thus the glass, A B, causes the rays which fall from the object, O, to become more divergent; and the lens of the eye, D, which is too convex, then converges the rays, and the image or focus is thus thrown as far back as the retina, R. Without the aid of concave glasses, near-sighted people cannot see objects at a distance with distinctness. As age advances, the eye becomes flatter, and sometimes those who were near-sighted in youth, are able in old age to see without glasses of any kind.

---

495. Why do short-sighted people use concave glasses? Explain the figure.

496. There is another defect of vision called *lo sightedness.* This arises from a want of suffic convexity in the crystalline lens. After middle and sometimes earlier, the eye becomes flattene consequence of the decay and shrinking of the refi ing humors. The change is denoted by a tendenc hold a book at a greater distance when reading. is because the rays of light are not converged by flattened crystalline lens sufficiently to bring them focus on the retina; but this focus, or the image o object, would be formed at a point beyond. But a vex lens interposed between the object and the by bending the rays to a greater convergence, br the focus forward, and the image will be formed the retina. Thus the spectacles worn by aged sons are usually convex lenses. They do for the that portion of the labor of bending the rays of l which it has not the ability to perform for itself. functions of the eye being thus aided, the benefi sight are secured.

Fig. 97.



Let C D present the of the eye, A B a con glass or spe cle lens; then the object, *o*, at about six inches f the eye, will form a perfect picture of the object a the retina. But if the lens, A B, be removed, image will be confused, and it will be necessar withdraw the object to a greater distance. In s cases, very small objects may not be distinguished the eye at any distance without the aid of an artif lens.

---

496. What is the cause of long-sightedness?—How does a vex lens assist the long-sighted?—Explain the figure.

Optical Instruments.

497. There are a great variety of optical instruments; the most important are Spectacles, the Microscope, Camera-Obscura and Telescope.

498. Spectacles are lenses mounted upon a metallic frame, so that they can be conveniently worn before the eyes. The spectacles worn by aged people are convex glasses or lenses, which assist the flattened crystalline lens of the eye to converge the rays of light. The common eye-glasses carried by near-sighted people, are *concave* lenses which counteract, by their divergence, the effect of too much roundness of the refracting lens of the eye.

The Microscope.

499. The microscope* is designed to assist the eye *in viewing minute objects.*

500. A double convex lens, or a small globe of glass, is the simplest kind of microscope. When applied to small objects, as the stamens or pericarp of a plant, the surface of a crystal, or the letters of a book, it exhibits parts not visible to the naked eye, and magnifies such as are visible.

501. Without the aid of the microscope, we cannot view objects distinctly if held nearer to the eye than

* From the Greek *micros*, minute, and *scopeo* to see.

497. Which are the most important optical instruments?

498. What are spectacles?—How do the spectacles worn by aged people differ from the eye-glasses of the near-sighted?

499. What is the use of the microscope?

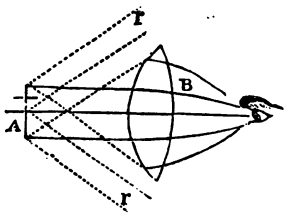
500. What is the most simple microscope?—What is the effect produced when small objects are viewed by the microscope?

501. Do we continue to see small objects more distinctly, the nearer we bring them to the eye?—What is meant by the limit of distinct vision?—What is the cause of the confusion of sight which takes place when objects are brought nearer than the limit of distinct vision?

three or four inches. For when an object is brought nearer and nearer to the eye, we at length reach a point within which sight becomes confused. This point is called the *limit of distinct vision*, and varies a little in different persons. The cause of this confusion of sight is, that the divergence of the rays of light from a near object is too great for the refracting power of the crystalline lens of the eye to collect them so that an image may be formed on the retina.

502. Thus, if an object, as the cross at A, be placed within an inch or two of the eye, the rays A r, A r, which proceed from it, are too divergent to be refracted so as to form a focus on the retina. But let the same object be viewed at the same distance from the eye by the assistance of the convex lens B, whose focal distance is B A, those rays diverging from the object which fall on the surface of the lens, will be refracted at its two surfaces, and emerge from it nearly parallel to each other, consequently the object is capable of being viewed by the eye on the side B, under a greater angle than it could be seen without the lens.

Fig. 98.



503. The object being now seen under a greater angle, is magnified; and minute portions, which were before invisible, because they did not occupy sufficient space on the retina, are now brought into view.

504. Even by looking through a pin-hole in a piece of colored paper, the letters of a book will appear

---

502. Illustrate this by a figure, and show how this defect may be remedied by the use of a convex lens.

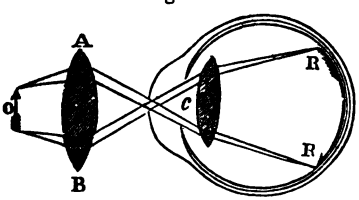
503. Why is the object magnified?

504. Why do small objects appear magnified when seen through a pin-hole?

larger and more distinct, than when seen in the ordinary way. The greater distinctness is owing to the exclusion of the *diverging* rays of each pencil of light, which, falling obliquely on the eye, are not brought exactly to the focus with the central rays, and therefore tend to confuse an image. The smallness of the pin-hole allows only the axes or central lines of the several rays to pass, and these proceed in lines almost parallel. Through such an aperture, letters appear very large and distinct, when the book is held within an inch of the eye. On removing the perforated paper, and attempting to look at the letters at the same distance as before, there is no distinct vision.

505. The single *microscope* consists of a convex glass, called a magnifying glass, in the focus of which is the object. By means of the converging power of the magnifier, the eye may be brought very near the object. The rays from the object at O, being bent at A B, proceed nearly parallel to the pupil, C, and fall on the crystalline lens, D, in such a manner as, when again refracted, to form a magnified image on the retina, R R. The more convex a lens is, the shorter is its focus, and the shorter the focus of a lens, the greater is its magnifying power.

Fig. 99.



506. It is important for many purposes, to know the exact magnifying power of a microscope; that is, whether it makes an object appear ten, fifty, or a thousand times larger than when viewed by the naked eye.

---

505. Describe the single microscope.—On what depends the shortness of the focus in a lens?

506. What is meant by the magnifying power of a microscope?

507. This magnifying power depends on *the difference* of the distance of the object from a lens, and the distance when seen without its assistance; or in other words, *on the ratio between the focal distance of the lens and the limit of distinct vision.* The latter point varies in different persons and at different periods of life in the same person.

508. In reading, the most common distance at which we hold a book from the eyes is probably about ten inches. When we examine the minute parts of a flower or an insect we hold the object nearer.

509. *The focus of the eye* has been called ten inches by some writers, because this number being a decimal, forms an easy multiplier or divider in optical calculations. Thus in a lens which requires, for distinct vision, the object to be one inch from it,—that is, from the centre of the lens,—we must divide 10, the limit of distinct vision, by 1, which will give 10; therefore such a lens will increase the apparent size of an object *ten* times.

510. An inch lens then is said to have a magnifying power of 10; but this only denotes the increase of the length and breadth of an object. Such a lens has, in fact, a magnifying power of one hundred; that is, the magnified image would, in its superfices, occupy one hundred spaces, when the real object would occupy but

---

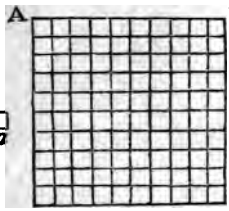
507. On what does the magnifying power of a lens depend?—Does that point called the limit of distinct vision vary?

508. How far do persons usually hold a book from the eye, when reading?—Suppose we examine some very minute object.

509. Why is the focus of the eye usually called ten inches?—Suppose a lens which requires, for distinct vision, the object to be within one inch from it.

510. What is the real magnifying power of an inch lens?—Explain the figure.

Fig. 100.

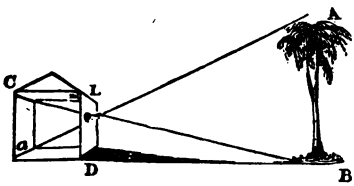


one. Thus, suppose the square, *a*, to be the real object, and A B, its magnified image. By counting the square it will be found that the image is ten times longer and broader than the object; but there are one hundred squares, each as large as *a*; therefore A B, is, in reality, one hundred times larger than *a*.

Camera-Obscura.

511. *Camera-Obscura** is either a closed room, in which the light can fall only through a small aperture, or an optical box in which exterior objects are represented on a smaller scale. Let C D represent a large box with an aperture at L, where is fixed a convex lens of such a curvature that the focus of parallel rays falls upon the opposite wall. The object A B being at a suitable distance, an inverted image of it will be formed on a screen or on the opposite wall; for the pencil of light which proceeds from A will converge to *a*, and the pencil from B will converge to C; and the intermediate points of the object will be reflected between *a* and C. The picture is viewed from an opening in the top of the box A plane mirror may be so placed as to reflect upon the

Fig. 101.



* Literally meaning a dark chamber.

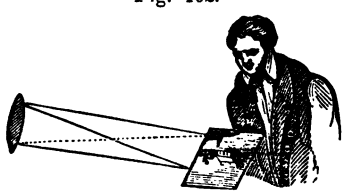
511. What is the Camera-Obscura?—How are objects seen in a Camera-Obscura?—How may a mirror be used in a Camera-Obscura?

lens the object to be delineated; in this, the camera-obscura bears an analogy to the *solar microscope.* When artificial light, as that of a lamp, is used instead of solar light, we have then the *magic lantern.*

512. The eye is properly likened to a camera-obscura; the pupil being the aperture in the chamber; the crystalline lens, the convex glass which is placed just behind the aperture; and the retina the screen or wall on which an inverted image of the object is depicted.

513. If the dark chamber had a soul; and a communication by some contrivance like that of the optic nerve, could convey the image formed upon the screen to it, then the chamber, or rather the soul within it, could see. But the *image on the screen is inverted;* and does the soul within its chamber see things upside down? Some philosophers have asserted, that this is the case, and that experience alone teaches the child to regard objects in their true position. But let us, in the first place, consider that the soul has no material eyes, and therefore that there can be no analogy between the operations of the mind and the eye in the act of seeing; and secondly, if the soul were behind the screen and looking *down* upon the inverted picture, (like the man in the figure,) the objects there delineated would appear in their true position

Fig. 102.



512. In what respects is the eye like the Camera-Obscura?

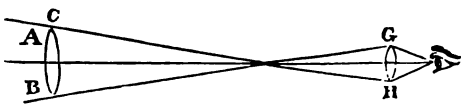
513. In what case could the Camera-Obscura see?—What have some asserted with respect to our seeing objects inverted?—What two objections are there to this?

Telescope.

514. The microscope and telescope are used for very different purposes; the one to examine minute objects placed very near to the eye, and the other to view large and distant objects. The telescope does, indeed, make use of the microscope in its operations, or rather an image is first formed of a distant object by means of a convex lens or a concave mirror, and then viewed and magnified with a microscope. A refracting telescope has the image formed by means of a *convex lens*. A reflecting telescope has the image formed by means of a *concave mirror*.

515. The astronomical telescope is the most simple of this kind of optical instruments; it consists of two *convex lenses*, an object-glass, and an eye-glass. The object-glass is directed towards the object; the eye-glass is at that end of the instrument at which the eye is applied.

Fig. 103.



Suppose A B to represent rays from some distant object, as a star; then the image formed by the object-glass, C, being viewed through the eye-glass, G H, will be magnified according to the magnifying power of the lens, G H. Thus, if the object-glass have a magnifying power equal to 10, and that of the eye-glass be equal to 6, the object will be magnified 60 times, because 10 multiplied by 6 equals 60. The image will be invert-

514. Different objects of the microscope and telescope.—In what way does the microscope assist the telescope?—Difference between a refracting and a reflecting telescope.

515. Describe the astronomical telescope.—Explain the figure.

ed, but this is not an important defect, because the use of this telescope is confined to observations of celestial bodies.

516. *Terrestrial telescopes*, used for ship and spy glasses, have two additional lenses in order to obtain erect views of the object.

517. The *reflecting telescope* has two concave metallic mirrors, with two *plano-convex* eye-glasses.

518. The telescope magnifies in proportion as it presents objects under an angle greater than is presented to the naked eye. The moon, for example, appears to the naked eye under an angle of half a degree; consequently, a telescope magnifies one hundred times when it represents the moon under an angle of fifty degrees. A telescope which should magnify one hundred and eighty times, would represent the moon under an angle of ninety degrees, in which case it would appear to fill one half of the visible heavens.

519. Euler, a celebrated German philosopher, wished, as the thing of all others most desirable, that he had a telescope which would magnify one hundred thousand times, so that he could then see the moon as if only half a mile distant, and observe the inhabitants and animals which may be upon it. But the little boy might with equal propriety wish that his rocking-horse were alive, and the little girl that her doll would talk. There are limits to human efforts; and it is not probable that men will ever build a tower high enough to reach the heavens, or construct a telescope which will make them so near neighbors to the celestial orbs, as to enable them

---

516. Why have terrestrial telescopes two additional lenses?

517. Describe the reflecting telescope.

518. How does the telescope magnify objects?—In what case might the moon be so magnified as to appear to fill half the visible heavens?

519. What was the wish of Euler?—Is it probable that this will ever be accomplished?

to inspect the operations which may be going on among their inhabitants.

520. The great telescope of Sir William Herschel was four years in building; it was forty feet in length, and the great mirror was four feet in diameter; it magnified six thousand times. Its focal length was forty feet. The star Sirius, when viewed through this telescope, appeared of the size and brilliancy of the sun. A sixth satellite of Saturn was discovered the day on which the telescope was completed.

CHAPTER XXXII.

Shadows—Decomposition of Light—Rainbow—Absorption of Light.

Shadows.

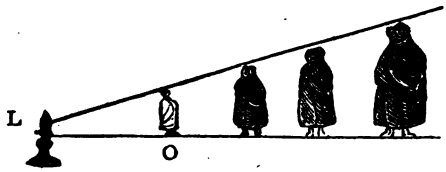
521. Two things are necessary for the formation of a shadow; first, a luminous, and second, an opaque body. The opaque body intercepts the passage of the rays from the luminous body, and causes darkness beyond it; and this produces upon the wall or screen, what is called a shadow, it being a dark image of the opaque object. Darkness, you will recollect, is but a negative; it is merely the absence of light; as cold, of itself, has no actual existence, but simply denotes the absence of heat.

520. For what was the telescope of Sir William Herschel remarkable?

521. What two things are necessary to the formation of a shadow?—What is a shadow?

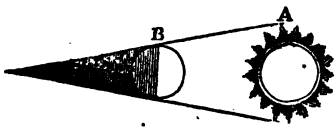
522. There are three things to be observed with respect to the form and size of shadows.

Fig. 104.



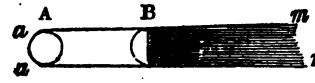
1st. Where the luminous body is smaller than the opaque body. Let L be a luminous body, smaller than the opaque body, O. It is evident from the divergence of the rays, that the shadow will be larger in proportion to its distance from its object.

Fig. 105.



523. 2d. When the luminous body is smaller than the opaque body. Thus, let A (the luminous body, the sun,) and B an opaque body, (the earth) the shadow will be in the form of a cone, and will gradually diminish in size till it terminates in a point.

Fig. 106.



524. 3d. When the luminous body is of the same magnitude as the opaque body. The shadow will be a cylinder. Thus, let A be a luminous body of the same magnitude as B. The lines *a m* and *a n* a

---

522. What is the effect when the luminous body is smaller than the opaque body?

523. When the luminous body is larger than the opaque body?

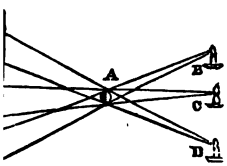
524. When the luminous body is of the same magnitude as the *opaque body*?

; and if the shadow of B were extended to infinity, ɔuld be cylindrical.

5. The darkness of a shadow is in proportion to intensity of light, although as surrounding objects ct light, the shadow itself will be, in some measure, iinated. Were it not for this, shadows would ap- perfectly black.

6. A number of lights will cause as many shadows e same object; that is, in case the lights are not ted in the same line of direction. Suppose a ball,

Fig. 107.



A, to receive light from three lamps, B, C and D; the light B will produce the shadow *b;* the light C will produce the shadow *c*; and the light D will produce the shadow *d*; but the shadows will not be very dark, because they receive some light from the two lamps which are out of line of direction. The ball hides the light from ımp C; but the wall at the place of the shadow *c* ıminated by the other two lamps.

Decomposition of Light.

7. Light is not a simple substance, but the *white* which comes from the sun, or any other luminous , may be decomposed.

8. Experiments to show the compound nature of are usually made with the *prism*. The optical a is a triangular piece of glass, peculiarly fitted, by ıape, for refracting the rays of light. By means ıch a prism, Newton proved that light consists of

. To what is the darkness of a shadow proportioned?—Why ɔt shadows perfectly black?

. In what case are many shadows formed of one object?— in the figure.

. Is light a simple substance?

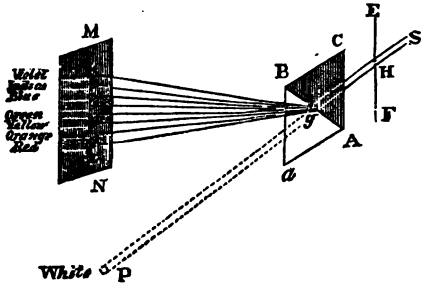
. What did Newton prove by means of the prism?

seven different kinds of rays, varying in color, gibility, and other qualities.

529. His experiments may easily be repeate a room be darkened, and admit a beam of light ly through a hole in the window shutter. If th of light be received upon a screen* or upon th luminous spot, only, will appear; but if a p placed before the beam of light, the rays will be of their straight forward course, and in this re they will separate, and arrange themselves screen according to their different degrees of gibility.

530. The annexed figure will illustrate this ment. E F represents the window shutter; hole in the shutter; S, the beam of light, whic out being interrupted, would go on in a strai

Fig. 108.



* A piece of white paper, or the white wall, will serve t of a screen, but a sheet of drawing paper fixed to a moves is the most convenient.

529. How may the same experiments be repeated?—S beam of light to fall upon the screen.—What will be th placing a prism before the beam of light?

530. Explain this by a reference to the figure.—What i spectrum?—Which of the two rays are at the extreme p spectrum?—Why is the red ray said to be the least re and the violet ray the most refrangible?

and form a round white spot at P. B A C is a prism whose refracting angle is at A. The beam of light falling on its first surface, C A, emerges at an equal angle of refraction from its second surface, B A, in the direction *g* G. Now we should expect, from the ordinary examples of refraction, that this beam of light, which before fell upon P, would only change its direction, and fall somewhere upon M N. But, instead of a round white spot, there appears on the screen, M N, an oblong image, K L, divided into seven colored spaces of unequal extent, and arranged in the order represented, beginning with the red. This image is called the *solar spectrum.*

It will be seen that the red ray is nearest the line P H, in which the light would have proceeded, if it had suffered no refraction; while the violet is the most distant from this line; therefore the *red ray is the least refrangible*, and *the violet ray is the most refrangible.* The prismatic colors, as exhibited in the solar spectrum, are thus described by Thomson, the poet of the "Seasons" and of Nature.

> First the flaming *red*
> Sprang vivid forth; the tawny *orange* next;
> And next delicious *yellow*, by whose side
> Fell the kind beams of all-refreshing *green.*
> Then the pure *blue*, that swells autumnal skies,
> Ethereal played; and then of sadder hue,
> Emerged the deepened *indigo*, as when
> The heavy-skirted evening droops with frost,
> While the last gleamings of refracted light
> Died in the fainting *violet* away.

531. The various colored rays of the spectrum may be collected by a convex lens, and when the image is received on a screen, a circular spot of white light is

---

How does the poet Thomson describe the prismatic colors?

531. How can the colored rays of the spectrum be collected so as again to form a beam of white light?

produced. Thus by *synthesis*, as well as analysis, is proved the compound nature of light.

Rainbow.

532. The rainbow shows the prismatic spectrum on a great scale. It is caused by the *reflection* and *refraction* of light, by means of drops of water, which produce the effects both of *convex mirrors* which *reflect*, and *convex lenses* which *refract* light.

533. It is when the sun may be seen shining through falling rain-drops, that we see the rainbow. If drops of rain were flat instead of round, rays of light would be reflected by them to the earth without being divided into prismatic colors, and the rainbow would appear an arch of glittering colorless light. But the spherical drops first bend or refract the rays, dispersing the prismatic colors, and then reflect them in the varied colors, and in the order they are exhibited in the prism.

534. The arched appearance of the rainbow is owing to the refracted rays being visible to our eyes only at certain angles.

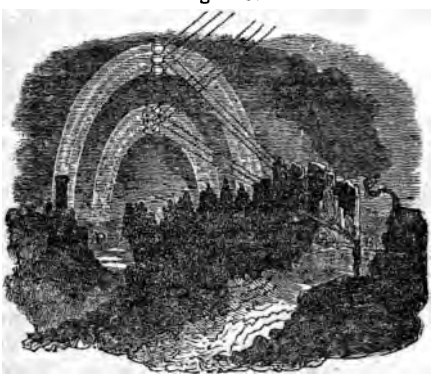
---

532. What causes the rainbow?

533. When do we see the rainbow?—Suppose that the drops of rain were flat instead of round.—How do the spherical drops affect the sun's rays?

534. To what is the arched appearance of the rainbow owing?—How can you illustrate this?

Fig. 109.



Thus, if a line be drawn horizontally from the eye of the spectator, as E P, it is evident that angles formed at the eye, or the point E, with this line, of a certain dimension in every direction, will produce a circle. Suppose three drops of rain, A, B, C, to be represented as in the rainbow. It will appear that the angle C E P is less than the angle B E P, and that the angle A E P is the greatest of the three. This larger angle is formed by the red or least refrangible ray, the middle one by the green, which is also the middle of the spectrum, and the smallest by the violet or most refrangible ray.

Absorption of Light.

535. The most transparent bodies in nature, as air and water, when in sufficient thickness, are capable of absorbing a great quantity of light.

536. On the summits of high mountains, more stars are visible than in the plains below, because the light

535. Is light absorbed by all bodies?

536. Why are more stars visible on the summits of high mountains, than in the plains below?

of some is wholly obscured by the atmosphere. On looking up through a considerable depth of water, luminous objects are scarcely visible.

537. The red color of the morning and evening clouds is owing to the absorption of the other colored rays by the air; and the noonday sun, when viewed from a diving-bell in the depth of the sea, from a similar cause, appears of the same hue. It is supposed that the light absorbed is *stopped* by the particles of the absorbing body, and remains within it.*

538. All the light that is not either *absorbed* or *transmitted*, is reflected, and the body assumes the color of the *reflected ray*.

539. Color is not an *essential*, but a secondary property of matter; it arises from the action of matter upon light. Thus a white cloth *reflects* all the rays; but when died yellow, the particles of the cloth acquire the property of absorbing all the other rays, and of reflecting only the yellow.

540. Bodies that reflect all the rays, appear white; those that absorb them all, appear black.

541. Colored bodies decompose light, by absorbing some of the rays, and reflecting others.

542. The color which a body *seems* to have, is, in reality, that for which it has no affinity, and therefore throws off at its surface, while the other colored rays hide themselves among its particles.

---

* Brewster's Optics.

---

537. To what is the red color of the morning and evening clouds owing?—What becomes of the light which is absorbed?

538. What gives to bodies their color?

539. Is color an essential property of matter?—From whence does it arise?—Why will a white cloth, after a certain process, appear yellow?

540. Why are some bodies white and others black?

541. How do certain bodies decompose light?

542. Is the color which a body seems to have, that for which it has the greatest affinity?

the dark there is no color, for where there
to be decomposed, there is none to be ab-
d none reflected.

---

is there no color in the dark?

PART VII.

ANIMAL MECHANICS.*

CHAPTER XXXIII.

Mechanism of the Human Body.

544. Having examined various machines contrived by man, we will turn our attention to one whose *maker is God.* This machine is the *human body*, which being finished and prepared for action, is furnished with a director, or superintendent, to regulate its motions, and keep it in order. This director is the human *mind.*

545. Let us consider farther that God is equally the creator of the directing Mind, as of the bodily machine; and we perceive that his works are infinitely superior to any thing that man can perform. God also creates, out of nothing, the materials with which he works; while man only uses those with which God furnishes him. Man could no more create a grain of sand, a blade of grass, or the smallest insect, than he could make a world.

* For the illustrations, and some part of the subject matter of this portion of the work, the Author is indebted to the "Library of Useful Knowledge," and Combe's "Principles of Physiology."

544. What machine are we now to consider?—Who is the director of this machine?

545. Who made both the machine and its director?—In what respect are the works of God superior to those of man?

6. The power of God would be terrifying, did we elieve that he is as good, as he is great and power--that he loves his creatures, and will make them y, if they will follow his directions, and try to ome the evil propensities, which, in order to try , God suffers to spring up in their hearts.

7. Some may say, "why does not God, if he is as well as powerful, make his creatures happy if do not obey him?" We answer, that there can) happiness without moral excellence, and there e no moral excellence where there is no choice een good and evil. A steam engine may do a great of good, but we cannot say it is virtuous; it is a machine, moved at the will of others, and incapaf happiness or misery.

8. Thus the body, which is a machine directed by ind, can only enjoy or suffer bodily pleasures or ; but the mind, when it overcomes temptation, it is conscious of virtuous intentions, is happy, eels secure in the favor and approbation of God;—e contrary, when it has departed from duty, the knows that it had the power to choose the better and that the reproaches of a guilty conscience are punishment.

9. The human body is exposed to accidents and es by which man, as a moral being, is tried, his athy for others excited, and his trust in God mani-. We are not, therefore, to consider the disor-

---

Why should not the power of God be a source of terror to atures?

Why does not God make all his creatures happy?—What ecessary in order to be virtuous?—Is a steam engine virtucause it does good?

What can the body suffer or enjoy?—When is the mind ?—When does it suffer?

Of what use are bodily diseases to man?—Do the disorders h the human machine is subject, imply any want of skill in hanician?

ders to which the human machine is subjected, as any proof of want of skill in the Mechanician, but as a necessary part of the plan of his work.

Bones of the Human Body.

550. The bones are the frame-work of the human body. These, by their hardness and strength, are fitted to support the softer and more flexible substances with which they are covered.

551. The parts which compose any piece of mechanism should be numerous and varied, in proportion to the variety of movements which it is designed to perform.

552. The human frame exhibits, in a most wonderful manner, this variety of parts, and is capable of an astonishing number of motions.

553. Let us examine the curious mechanism of the human frame;—and may no young person be so weak as to shrink from it, because he is called upon to study a *skeleton*. It is by means of such a study, that the surgeon is able to adjust dislocated bones, to ascertain the nature and extent of injuries done the human frame, and thus enabled to relieve suffering.—It is by this study, that we would lead you, not only to a knowledge of the structure of your own body, but to think more upon that Divine Wisdom by whom it was formed.

554. The bones entering into the composition of the human skeleton exceed 200 in number. Each bone is separate from, but intimately connected with the rest, and of a shape, size and construction in exact harmony

---

550. What constitutes the frame-work of the body?

551. To what should the number and variety of parts in any piece of mechanism be proportioned?

552. How is the human frame in these respects?

553. Of what practical use is the study of a skeleton?—To what religious object should this study tend?

554. How many bones are there in the human skeleton?—How is it with respect to their shape, size and construction?

with the kind and extent of motion which it is destined to exercise.

555. The three great divisions of the skeleton, are the head, trunk, and extremities. The first contains the brain ; the second includes the two great cavities, the *thorax*, or chest, and the *abdomen*, or belly ; and the third comprises the arms and legs, or upper and lower extremities. Each of these divisions presents a structure beautifully adapted to the purposes for which it is destined.

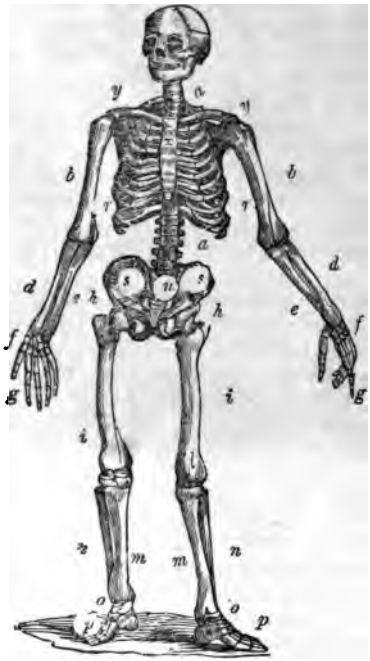
556. The head consists of the skull, and bones of the face. The skull affords complete protection to the brain, from all ordinary accidents, and also to the organs of hearing, seeing, smelling, and tasting. Protection, and not motion, being the sole object of its construction, the numerous bones of which it is composed, are joined to each other, not by moveable joints like other bones, but by a kind of dove-tailing, which combines the solidity of continuous structure, with the advantages which their separation gives in facilitating growth, and interrupting the extension to all the parts, of the injuries inflicted on one.

---

555. What are the three great divisions of the skeleton ?—What does the head contain ?—What the trunk ?—What are comprised in the third division ?

556. What are the parts of the head ?—Of what use is the skull ?—Why has it not moveable joints, like other bones ?

Fig. 110.



557. The *trunk* (see figure,) consists of the *sp* the *ribs r r*, the *sternum x*, and the *pelvis s* spine, vertebral column, or back-bone, *a a*, sup the other parts, and is a very remarkable piec chanism, being at the same time, *elastic*, flexi

557. What are the parts of the trunk?—Of what imp the spine?—Of how many bones is the spine composed *are the cervical* vertebræ?—What the dorsal?—What th —*Where does* the base of the column rest?

ng. It is composed of twenty-four separate bones, ed *vertebræ*,* because the body turns on them as on vot. Of these, seven, called *cervical*† vertebræ ng to the neck; twelve, connected with the ribs, called *dorsal*,‡ to the back; and five, called *lumbar*, ie loins. The base of the column, rests on the *um*, *u*, which is closely compacted between the es of the pelvis, *s s*.

58. The vertebræ are firmly bound to each other in a way, as to admit of bending and extension, and rtain degree of rotation, while by their solidity firm attachment to each other, great strengh is se- d.

59. Some conception of this strength may be ied, when we consider the great loads that athletic are able to carry on their shoulders, or lift with hands; the whole weight being necessarily borne he vertebræ of the loins. As the space occupied ie abdomen, gives large outward dimensions to this on of the body, it is only when our attention is d to the peculiar structure of this part of the hu- frame, that we perceive that the whole force ex- l by man in his most strenuous efforts, centres ul- tely in the vertebral column, or back-bone.

60. While the fore part, or body of the vertebræ, af- s support to the superincumbent parts; the project- ridge behind, and rugged *processes* at the sides,

* From the Latin, *vertere*, to turn.
† From *cervix*, the neck.
‡ From *dorsum*, the back.
‖ *Process*, as here signified, is a projecting part.

58. How are the vertebræ connected with each other?
59. What part of the body sustains the principal weight of y burdens?
60. What is the office of the body of the vertebræ?—How is the formed which contains the spinal marrow?—What is the spi- arrow?—(see note, page 194.) Of what use is the cushion of age and ligament?

combine with it to form a large tube or canal, ext from the top to the bottom of the column; in this which is about an inch in diameter, the *spinal m* is contained and protected. Between each two vertebræ, a thick, compressible cushion of c and ligament† is interposed, which serves the purpose of uniting the bones to each other, of ishing and diffusing the shock in walking or l and of admitting a greater extent of motion tha bones were in more immediate contact.

561. The ribs, *r r*, twelve in number, on ea are attached by their heads to the spine, and other cartilaginous extremities, to the *ster* breast-bone, *x*. The seven uppermost are call ribs, because each of them is connected direc the sternum, by means of a separate cartilag five lower ribs are called *false* ribs, because on of them are loose at one end, and the cartilage rest run into each other, instead of being se prolonged to the breast-bone. The use of the to form the cavity of the chest, for the recep protection of the lungs, heart, and great blood and to assist in respiration by their alternat and falling. This action enlarges and diminis size of the chest, and the capacity of the lungs

562. The *pelvis*, *s s*, is formed by the br bones which support the bowels, and serve fo *ticulation*‡ of the thigh.

* The spinal marrow is a substance similar to the brai pears to be of equal importance to life and the powers of Injuries to the spinal marrow, have been known to prod nity; and it is well known, that the same event happens quence of injuries to the brain.

† Cartilage, in common language, is called gristle. A is a band or cord, which binds.

‡ Meaning the juncture, or joints of bones.

561. How are the ribs attached to the spine and sternum is the use of the ribs?

562. How is the pelvis formed?

A general notion of the appearance and uses of the bones may be obtained from examining Fig. 110.

563. The bones of the *upper extremities*, are the *scapula* or shoulder-blade; the *clavicle*, or collar-bone, *y*; the *humerus*, or arm-bone, *b*; the radius, *d*, and the ulna, *e*, or bones of the fore-arm; and the small bones, *f* and *g*, forming the wrist, hand, and fingers.

564. The scapula is the broad flat bone lying at the upper part of the back, familiarly known as the shoulder blade, and so troublesome to many young ladies by its unseemly projection. It serves to connect the arm with the trunk of the body, and gives origin to many of the muscles by which the arm is put in motion.

565. The collar-bone, *y*, extends from the breast-bone outwards to the *scapula*. Its chief use is to prevent the arms from falling forward in front of the body; and hence it is wanting in the lower animals, whose superior extremities are much closer to each other than those of man.

566. The *humerus*, or arm-bone *b*, is adapted by a kind of ball and socket joint, to a corresponding surface in the scapula; it enjoys great latitude of motion, and is somewhat liable to dislocation.

567. The *radius* and *ulna*, *d e*, constituting the fore-arm, are connected with the humerus by a hinge-like joint, which admits readily of flexion and extension, but not of rotation; owing to the peculiar construction of this joint, it is rarely dislocated. The movements in turning the hand, are effected, not by the elbow-joint, but by the radius, *d*, moving upon the ulna, *e*, by means of joints formed for this purpose.

---

563. What are the bones of the upper extremities?
564. What is the scapula, and its use?
565. Where is the collar-bone, and what is its use?
566. Describe the humerus or arm-bone.
567. What bones constitute the fore-arm, and how are they connected with the humerus?—How are the movements in turning the hand effected?

568. The lower extremities consist of the *os-femoris*,* or thigh-bone, *i*; the *patella* or knee-pan, *l*; the *tibia*,† *m*; and *fibula*,‡ *n*, or leg-bones; and the *tarsal*§ bones, *o*, and *phalanges*,‖ *p*, composing the ankle, foot and toes.

569. The thigh-bone, *i*, is articulated by means of a large round head, deeply sunk into a corresponding hollow in the pelvis, *h*, freedom of motion being thus combined with great security. The thigh may be moved backward and forward, as in walking; and also outward and inward, as when sitting upon horseback, or with the legs crossed. The socket being much deeper than that of the shoulder-joint, the thigh-bone has not the same range of motion as the *humerus*, or arm-bone, but it has, proportionally, greater security.

570. The *patella*,¶ or knee-pan, is a small bone constituting the projection of the knee. It increases the power of the muscles which extend through the leg, and protects the front of the knee-joint.

571. The tibia, *m*, is the principal bone of the leg, and is the only one articulated with that of the thigh. Its lower end forms the projection at the inner ankle.

---

* *Os* is a Latin word signifying bone; *femoris* from *femur*, the thigh.

† From *tubia*, a tube, on account of its tube-like shape.

‡ From a Latin verb, *figo*, to fasten, so called, because it connects the tibia and the muscles.

§ From the Greek, *tarsos*, the instep.

‖ The plural of *phalanx*, meaning ranks of bones.

¶ Derived from *patina*, a Latin word signifying a little dish.

---

568. Of what bones do the lower extremities consist?

569. What two advantages are secured by the articulation of the thigh-bone?—How may this bone be moved?—How does it compare with the shoulder-joint, as respects motion and security?

570. What is the patella, and its use?

571. What is the tibia, and with what is it connected?—What is the fibula, and what does its lower end form?—What two bones *help to form* the ankle joint?

fibula, n, is the long slender bone at the outer side
: leg, the lower end of which forms the outer ankle.
ibia and *fibula* both contribute to the formation
ankle-joint, which, like that of the knee, is almost
d to flexion and extension, or in other words, to
ng, and stretching forth.

. The *tarsal* bones constituting the foot, display
mirable mechanism; they are very numerous, as
ɔe perceived by the various motions of which the
.s capable. The variety of steps taught by the
ng master, may serve as an illustration.

. Bones consist of *two kinds of substances,* viz.
of an *animal,* and those of an *earthy* nature.
ıe former, belongs every thing connected with
e and growth of bones; while to the latter, be-
he hardness and power of resistance by which
are characterized.

. In infancy, the animal portion greatly predom-
, and, consequently, the bones are, at that age,
ıratively soft, yielding, and elastic. In middle
he proportions are more equally balanced, and
the bones thereby acquire great hardness and
ty, they still preserve some elasticity. In old
n the contrary, when the earthy constituents pre-
ıate, they become dry, brittle, and comparatively
is.*

---

mbe's Principles of Physiology.

What can you say of the tarsal bones, and of the motions
oot?

Of what do bones consist?—With what qualities is the
substance connected?—What qualities belong to the earthy
ıce?

Why are the bones in infancy, soft and elastic?—What
condition in middle life?—Why are they dry and brittle
age?

CHAPTER XXXIV.

Tendons and Muscles.

575. The human body, though supported by its bony fabric, owes its power of motion, and its beautiful proportions, to *tendons* and *muscles.*

576. The bones are to the body, what the masts and spars are to a ship, they give support and possess the power of resistance; the muscles and tendons are to the bones, what the ropes and sales are to the masts and spars. Without the muscles and tendons, the bones could have no power to move or direct their position, and, a ship with only masts and spars would be but an unmanageable thing.

577. Had the human body consisted merely of solid bone, it would not only have been incapable of motion, but every external shock would have been communicated, with little diminution, to the whole system, as may be seen in a skeleton hung with wires; but, by means of the elastic cartilages and ligaments which are placed about the joints, free and extensive motion is secured; external shocks are lessened in their force, and diffused over the body in the same way as the elastic springs of a carriage lessen the jolting of the wheels, by diffusing the motion through the whole vehicle.

578. In the bones of the human body we find *col-*

---

575. Of what use are tendons and muscles?

576. To what parts of a ship may the bones, muscles, and tendons be compared?

577. Suppose the body had consisted of solid bone?—What effects have cartilages and ligaments?

578. In what respect may the human body be called a machine?

umns, *levers* and *pulleys*, and in the tendons and muscles we find the *cords* by which the more solid and inflexible parts are moved.

579. The *tendons* or sinews consist of fibres interwoven in bundles, in a manner fitted to resist great strains, or bear heavy weights. The tendons do, however, sometimes break, when after long disuse, they are suddenly called into exercise. Thus a lady, accustomed to little bodily exercise, playfully attempted to outrun a sprightly girl; they both started at the same moment, the lady threw her right foot forward with great force, and instantly felt the tendon of the heel* give way. The limb was now useless, and the ruptured tendon excruciatingly painful. Nature however, kindly and securely working, at length knit together the severed fibres, and the person after some weeks was able to walk, but the tendon remained weak for years. This proves the danger of gymnastic and callisthenic exercises when not regulated by prudence.

* This is called *tendon Achilles*, being the tendon in the heel of Achilles said to have been pierced by the arrow of Paris.

579 Of what do the tendons consist?—In what cases are the tendons liable to break?—What case is mentioned to show the danger of a sudden and violent motion of the sinews?

Fig. 111.

580. The figure, at A, represents a tendon, which in nature, is confined at the ankle by ligaments or cross straps. If this tendon, which terminates at B, took the shortest course to that point, it would act with greater force in drawing up the toe, but in this case the toe would move with less velocity. By taking the direction, C, close to the joints, the toes have the power of quicker and more elastic motion.

581. The muscles are those bundles of fleshy fibres which are found beneath the skin of animals, and appear as the red fleshy part of meat.

582. The muscles are composed of numerous small fibres of threads. Each muscle is separated from the others by layers of cellular membranes.* It is the fat which is contained in some of the cells of these layers, that gives roundness of outline; while a deficiency of cellular fat produces the sharp and angular forms of very lean persons.

583. Muscles are considered as consisting of three parts; the largest and most fleshy part called the *swell*, is the *middle;* the other two are the opposite ends, one of which is called the *origin*, the other the *insertion* of the muscle.

584. Motion is produced by the contraction of the muscles, acting upon, and changing the positions of the bones with which they are connected.

* By cellular membrane is meant a membrane containing small cells or cavities.

580. Explain the figure.
581. What are the muscles?
582. Of what are they composed?—How are they separated?—Where is the fat in the human body contained?
583. Of what parts do the muscles consist?
584. How do the muscles produce motion?

585. If a person stretch out his arm, he may be conscious that one set of strings or muscles have contracted or drawn themselves up, while another set are pulled out.

In order to bend a finger, a certain muscle contracts; in straightening the finger, the same muscle is extended.

586. Every muscle is provided with its *antagonist muscle;* their action has been compared to that of two sawyers, alternately pulling in opposite directions.

587. The mouth is kept in the middle of the face and its corners held in a true and regular position, by two muscles which draw against, and balance each other. If one of these muscles becomes weakened, the other will exert too much power, and draw the mouth to one side of the face.

588. The number of muscles in the human body is more than 400; they are placed in layers one above another.

---

585. What change takes place among the muscles in stretching out the arm, or bending the finger?

586. With what is every muscle provided?

587. What is the effect of two muscles drawing against each other near the mouth?

588. How many muscles are there in the human body?—How are they arranged?

Fig. 112.

589. The figure shows the outer layer of muscles in the human body, or those which appear on removing the skin.

The *sterno-mastoid** muscle, *f g*, is at the side of the neck, and turns the head to one side, or bends it forward.

The *rectus*† or straight muscle *b*, on the forepart of the thigh, contracts with great force in the act of kicking; its lower end, attached to the knee-pan and leg, approaches nearer to the upper or more fixed point, and pulls the leg strongly forward. The same contraction of this muscle takes place in walking.

The *sartorius*‡ or tailor's muscle, *c*, is the longest muscle in the human body. When this is put in motion, its course being oblique, the movement of the leg is not in a straight line, but in a cross direction, like that in which tailors sit at their work.

i i i are muscles which bend the body forward and pull down

* So called from *sternum*, the breast-bone, and *mastoideus*, like a breast.

† *Rectus*, straight.

‡ So called from *Sartor*, a tailor.

589. What does the figure represent?—Of what use is the sterno-*mastoid* muscle?—The rectus or straight muscle?—Describe the

the bones of the chest; *a k* and *l* are muscles which by their contraction bend the fore-arm.

590. We have shown that the contraction of the muscles produces motion in the animal frame; but what power is it which contracts the muscles? For though perfect in all respects, a muscle could not put itself in motion. It is the *nerves*, acting upon the muscles, which afford the stimulus necessary to produce motion.

591. The nerves are all connected with the brain, and consist of a substance resembling it in appearance. The optic and auditory nerves, or those on which depend the power of seeing and hearing, proceed directly from the brain, and are called *cerebral* nerves.* The nerves of the body generally, proceed from the *spinal marrow*, and are therefore called the *spinal nerves.*

592. The spinal marrow, itself, is but a continuation of the brain, extending from the head through the whole extent of the spine, and sending off, in every direction, nervous filaments which supply every minute fibre of every muscle.

593. We have now traced the cause of muscular motion to the nerves, and have shown that the nerves proceed from the brain. But we wish, moreover, to know what power it is which operates on the brain and nerves, and enables them to give motion to the muscles. We can, however, go no further; for when the

* From *cerebrum*, the brain.

sartorius or tailor's muscle.—What is the use of the muscles marked *i i i*, and *a k* and *l*?

590. What power produces motion in the muscles?

591. Of what do the nerves consist?—Which are the cerebral nerves?—Which the spinal nerves?

592. What can you say of the origin and extent of the spinal marrow?

593. Can we go beyond the nerves and brain in tracing the cause of motion in the body?

brain is laid open by dissection, nothing can be discovered but a soft whitish mass of matter. Yet this seems to be the *capital of the mind;*—the seat of its most important operations.

594. The nerves are the messengers which convey intelligence from the mind to the muscles, and the latter, obedient to the sovereign will, perform their assigned tasks.

595. In producing voluntary motion, there is, 1st. an effort of the *mind* called *will;* 2d. the *brain*, or organ on which the will acts; 3d. the *nerves*, which *carry* to the *muscles* the *command* of the *will;* and 4th. the *muscles*, by whose *contraction motion is produced.*

596. In view of our material frame, we may well exclaim, "What a piece of work is man!" We here find separate contrivances for motion of every kind, and for the action of the sentient organs, seeing, hearing, &c., and all without the least interference of one part of the machinery with any other. How many operations are necessary to enable a writer to transfer his thoughts to the minds of others, by means of the pen! First, the body must be supported erect, by the bones and muscles of the back; and the sitting posture calls into action, another set of muscles. In holding the pen, some muscles of the fingers are stretched out, and others contracted; while the eyes perform the office of directing the hand in forming the letters and placing them properly upon the paper. But what could this bodily machine do, were there not the directing mind to pull the muscles in the right way, and still farther, to bring forth from the chamber of thought, the ideas of which words are but the images?

---

594. What power impels the nerves to perform their operations?
595. By what series of causes is voluntary motion produced?
596. What is remarked respecting the study of animal *mechanics?*

597. Wonderful as is the animal machine, how absurd it is to neglect its study;—to live in ignorance of the mechanical laws that govern our own motions while we carefully investigate the structure of a flower or an insect, or study the mechanism of distant worlds

598. There is much indeed for the young to learn, for all sciences have their uses and advantages. But this consideration, instead of affording indolence an excuse, should inspire you with resolution to make new conquests in the regions of knowledge. And may you always remember that knowledge is worse than useless, unless accompanied with virtue, and the love and fear of God.

---

597. Concluding remarks.

VOCABULARY,

OR

EXPLANATION OF SCIENTIFIC TERMS.

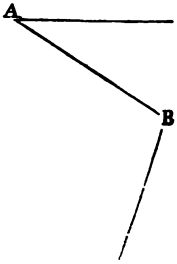
A.

Absorbent media. Substances which drink in, or imbibe the rays of light.

Accelerated Motion. Motion constantly increasing in velocity.

Action. Efforts of one body upon another.

Acute Angle. Sharp, opposed to blunt. Any angle smaller than a right angle, is an acute angle, as the corner at A. An obtuse angle, is greater than a right angle, as the corner at B.



Acoustics. The science which treats of sound and hearing.

Æriform. Having the form of air.

Ærostatics. The science of navigating the air.

Æronaut. One who navigates the air.

Air. A fluid surrounding the earth; filling all spaces otherwise vacant; very compressible and elastic, and pressing with the weight of fifteen pounds, upon every square inch.

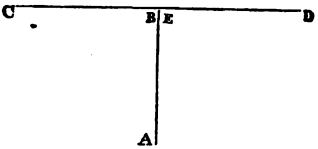
Air-gun. Like a common musket; it consists of a long metallic tube, adapted to receive a ball, into the breach of which is an opening to admit condensed air; this air, on being suffered to escape, propels the ball with great velocity.

Air-pump. A machine to expel air from a vessel called a receiver.

Altitude. The height of an object above the horizon.

Analysis. The act of separating or resolving a compound into its elementary parts.

Angle. When one line meets, or crosses another perpendicularly, at their point of contact, they form a right angle; thus the perpendicular line, A, in crossing the horizontal line, C D, forms two right angles at B and E. A *right* angle, is a square corner; it is also an angle of 90 degrees, for if it includes 1-4th of an arc of a circle, it forms a *quadrant.* If more than 1-4th of the arc of a circle, it is an *obtuse* angle. If less, an *acute* angle.



Angle of Incidence. Is the space contained between a ray which falls obliquely upon a body, and a line perpendicular to the surface of the body, at the point where the ray falls.

Angle of Reflection. The space contained between a reflected ray, and a line perpendicular to the reflecting point.

Angle of Vision. The space contained between lines drawn from the extreme parts of an object, and meeting in the eye.

Arc of a Circle. Any part of its circumference. (See *Segment.*)

Area. The surface enclosed between the lines which form the boundary of any figure, whether regular or irregular.

Aperture. A small hole or opening.

Atmosphere. The air we breathe, and which extends all around the earth, and above it, about the height of 45 miles.

Attraction. The tendency of bodies to approach each other, and to come in contact; it is of various kinds; as the attraction of Cohesion, of Gravitation, of Magnetism, Chemical attraction, &c. It is the opposite of repulsion.

Axis of Motion. The imaginary line, around which all the parts of a body revolve, when in rotatory motion.

Axis of a Lens or Mirror. A line passing through the centre of a lens or mirror, in a direction perpendicular to its surface.

Axle. A shaft or pivot upon which a wheel turns.

B.

Balloon. A hollow globe inflated with gas, or rarefied air.

Barometer. From the Greek *baros,* a weight, and *metron,* measure. An instrument for measuring the weight of the atmosphere.

Base-line. *In surveying,* a *base-line* is a line measured on the

surface of the earth, and assumed as an origin from whence the angular and linear distances of remote objects may be determined.

Body. The same as matter, or substance. It may be either solid, liquid, or æriform, and includes every thing we can perceive by our senses

Burning-glass. A *lens* or *mirror*, by which the rays of light are brought to a focus, so as to set combustible bodies on fire.

C.

Camera-Obscura. Literally a *darkened chamber.* An instrument for taking a picture in miniature of external objects, by means of the rays of light from such objects, collected to a focus, by falling on a convex lens, placed in a small, circular aperture, in the window of a darkened chamber, or box.

Capillary Attraction. That force which causes liquids to rise in hair-like tubes, called *capillary*, from *capillus*, a Latin word, signifying hair. Liquids in which one end of such tubes is immersed, will ascend and remain suspended in them.

Cataract. A fall of water over a high precipice;—a cascade.

Centre of Gravity. That point within a body to which all its particles tend, and where they incline to remain at rest.

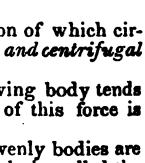
Centre of Motion. That point about which the parts of a revolving body move.

Central Forces. Those forces by the co-operation of which circular motion is produced; that is, the *centripetal and centrifugal* forces.

Centrifugal Force. The force with which a revolving body tends to fly from the centre of motion. The direction of this force is in a tangent to the path the body describes.

Centripetal Force. That power by which the heavenly bodies are drawn towards points out of their rectilinear path, is called the centripetal force.

Circle. The circle is a perfect figure contained by one line, which is called the circumference, and is every where equally distant from a *point* within, called the centre.



Circumference. The boundary of a surface, as that which surrounds the centre of a circle.

Cohesion. The power that binds particles of matter into solid masses.

Color. The appearance of the surface of bodies to the eye; their tint, hue, or dye.

Compression. The act of squeezing together.

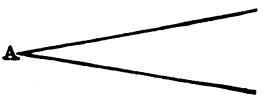
Concave. A hollow surface, like the inner surface of the crystal of a watch.

Condensation. The act of forcing the particles of matter closer together.

Cone. A body resembling, in form, a sugar- loaf.

Contact. Touching.

Converging. Tending to the same point, as the two lines which meet at A.



Convex mirror. A polished, curved surface, bulging out like the upper surface of a watch-glass, made either of metal, or glass rendered opaque by a metallic coating.

Crystal. An inorganic substance having a regular form.

Curve line. A line crooked, bent, inflected.

Curvilinear. Consisting of a bent or crooked line.

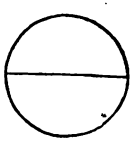
Cylinder. A body in the form of a roller; it may be either solid or tubular.

D.

Density. Compactness of parts and texture; solidity. A body is heavy in proportion to its density.

Diagonal. A line drawn from angle to angle of any figure having four sides. (See *Parallelogram.*)

Diameter. The line which, passing through the centre of a circle, divides it into equal parts.



Dilate. To increase in size. Most bodies dilate by being heated.

Disperse. To scatter, to dissipate. To disperse rays of light is to drive or scatter them in various directions, as in the prism.

Divergent. Spreading out from a point. (See *Converging*, where the lines diverge from the point A.)

Divisibility. The property of being divided.

Double refraction. The power which some substances possess of transmitting a ray of light in two pencils instead of one.

Dynamics. The science of force and motion, from the Greek, *dunamis*, signifying force. Mechanics is divided into two branches; *dynamics*, which considers bodies as submitted to the influence of forces which are not in equilibrium; and *statics*, (which see, page 208.)

E.

Echo. The reflection of sound. The reflection of sound takes place according to the laws that govern the reflection of elastic bodies.

Elements. Substances that cannot be decomposed, as oxygen, nitrogen, hydrogen, the metals, &c.

Elasticity. The property which bodies possess of resuming their original form, when pressure is removed.

Ellipsis. An oval figure. It differs from a circle in having two centres or points, called *foci.*

Engine. Any mechanical contrivance, in which various movements and parts concur to one effect.

Equilibrium. Originally a Latin word signifying balance; forces balancing each other are in equilibrium.

Ether. An element more fine and subtile than air, supposed to be the matter of the higher regions above the atmosphere.

Evaporation. The change of a liquid to a vapor.

Exhalations. All those particles which arise from the earth or water, and mixing with the atmosphere, form vapor.

Expansion. The act of spreading out, or enlarging the volume of a body.

Extension. One of the essential properties of matter, by which a body of a certain bulk occupies a certain space, to the exclusion of other matter.

F.

Figure. Form or shape is one of the essential properties of matter, because all matter must possess some form or shape. Figure may be resolved into extension, it being but its boundary.

Fluid. A substance having parts or particles easily separated, and which readily flow or glide over each other, or matter in which the powers of attraction and repulsion are balanced.

Focus. The point where the rays are collected by a burning-glass; also the point in the axis of a lens where the rays meet and cross each other. Also a certain point in the axis of a curve.

Force. The power that acts upon a body, either to create or stop motion.

Fountain. The head or spring of a river. A jet or spout of water forced upwards, by the weight of other water, by the pressure of air, or by some other mechanical pressure.

Friction. The act of rubbing two bodies together; the resistance in machines caused by the motion of one body upon another.

Fulcrum. The prop on which a lever acts.

G.

Gas. The elastic or expanded state of any fluid or substance formed by the action of heat.

Geometry. The science which treats of lines, surfaces, and solids, and investigates their forms and proportions.

Globe. A sphere or ball. It has a point in the centre of its magnitude, from which the circumference or surface is every where equally distant.

Gravity. The attraction of matter; weight. By the force of gravity a stone falls to the earth, and the heavenly bodies tend toward each other.

Gravity, specific. The relative weight of different bodies in regard to some standard, as water.

H.

Hemisphere. Half a sphere or globe. A plane passing through the centre of the globe will divide it into hemispheres.

Horizon. The line that bounds our view where the earth and sky seem to meet; and which cuts the heavens into two equal parts of 180 degrees each.

Horizontal. A line parallel to the horizon; level, not inclined or sloping.

Hydraulics. From the Greek *udor*, water, and *aulos*, a pipe. The science which treats of water in motion, and of the means by which it may be used for moving machinery and other purposes.

Hydrostatics. From the Greek, *udor*, water, and *statos*, standing; it treats of the weight, pressure, and motion of fluids.

Hydrogen. From *udor*, water, and *gennao*, to produce. The basis of water. Combined with carbon, it produces the gas lights.

Hydrometer. From *udor*, water, and *metron*, measure. An instrument used to ascertain the specific gravity of different fluids. The strength or proof of spirits is tried by this instrument.

Hygrometer. From *ugros*, moisture, and *metron*, measure. An instrument by which the moisture of the air is measured.

I.

Ice. Water condensed by frost, or by the absence of heat.

Image. In optics, the picture of any object which we perceive either by reflected or refracted light. It is a fact taught by philosophy, that man does not see objects, but images.

Impenetrability. That property of matter, which excludes every thing else from occupying the same space with itself.

Impetus. A force, the intensity of which is determined by the mass of body and the square of its velocity, conjointly. Synonymous with momentum.

Imponderable. Without perceptible weight.

Incidence of light. The angle which rays make with the perpendicular to a surface upon which they fall.

Inclined plane. One of the simple mechanical powers. Any plane surface inclined to the horizon, may be so denominated.

Inertia. The disposition of matter to remain in its present state, whether of rest or motion.

L.

Labyrinth. A place formed with many windings; an internal part of the ear.

Lateral. Sideways.

Lens. A transparent substance with curved surfaces. The glasses of a telescope and of spectacles are lenses. A lens may be convex on both sides, or it may have both sides concave; one side may be convex and the other concave; one side plane and the other convex; or, lastly, one side may be plain and the other concave.

Lever. One of the simple mechanical powers. It is a stiff bar of wood or metal, supported by a prop or fulcrum, by which heavy bodies are pryed up, or moved.

Light. The medium which enables us to discern objects. It is emitted from a luminous body, and passes into the eye, by which means vision is excited; that is, an image of the body is impressed upon the retina by the rays of light.

Luminous bodies. Those which emit light from their own substance, and not by reflection. But the term luminous is, in common language, applied to such bodies as shine by reflected light; thus the moon is often called a luminary.

M.

Machine. Any instrument by which a mechanical effect is produced, whether it be simple, like a needle or a lever, or complex, like a clock or a power-loom.

Magic lantern. An optical instrument, by which transparent pictures painted upon glass are exhibited upon the wall of a darkened room.

Matter. Every substance, however large or however minute, which has length, breadth, and thickness.

Mechanics. The science of the equilibrium and motion of bodies.

Medium. Is any body that transmits light. It is that also in which any substance moves.

Mercury, or quicksilver. A metal which remains fluid at the common temperature of the atmosphere. Intense cold will render it solid. Its great use in philosophy is in the Thermometer and Barometer.

Microscope. An instrument by which minute objects which would otherwise be invisible, are magnified so as to be seen by the naked eye.

Mirrors. Polished surfaces of metal, or of glass coated with metal, for the purpose of reflecting the rays of light, and the images of objects.

Mobility. A property of matter which renders it capable of being moved.

Momentum. Force computed by the mass of a moving body and its velocity, conjointly. The quantity of motion in a moving body.

Motion. A constant change of place.

N.

Natural Philosophy. The science which explains the causes of the various properties of bodies in general, as shown by the changes they undergo, or the changes which they may occasion in other bodies under certain circumstances.

O.

Obtuse angle. Any angle greater than a right angle, or one that contains more than ninety degrees. (See *Acute Angle.*)

Octagon. A figure with eight sides and eight angles.

Opaque. Dark, not transparent; refusing a passage to the rays of light. If all bodies were transparent we could see nothing; air is invisible, on account of its transparency.

Optics. The science of light, of colors, and of vision.

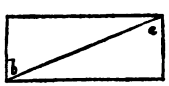
Orbit. The line or path in which a primary planet moves in its revolution round the sun; or a secondary planet, in its revolution round its primary. These orbits are not exact circles, but elliptical or oval.

P.

Parabola. A section of a cone. The curve-line which a cannon-ball describes, in rising and falling, when propelled from a cannon's mouth, is a parabola.

Parallax. The angle under which we view an object; it therefore diminishes as the distance increases. By the *Parallax of the heavenly bodies*, is meant the difference between their real and apparent positions.

Parallelogram. An oblong figure with four sides, having its opposite sides equal and parallel to each other. The line *a b* that crosses the figure from one angle to another is a *diagonal* line.



Parallel lines. Lines equally distant from each other in every part; and which, if extended to an infinite distance, would never meet.

Pendulum. A body suspended from a point, by a rod or line, and performing vibrations backward and forward. Pendulums of the same length, perform their vibrations in the same time, whatever may be their weight, or whether their swing or arc of vibration be long or short.

Percussion. The striking of bodies against each other. The force of this depends on the momentum of the striking body.

Periphery. Circumference.

Perpendicular. That which forms an angle of 90 degrees with the horizon. When two lines meet at an angle of 90 degrees, they are perpendicular to each other. Thus the lines A B and C D, (see Angle) are perpendicular. In common language, perpendicular means upright, vertical, the opposite of horizontal.

Phases. The various appearances of the disc, or face of the moon, and of the planets, when illuminated by the rays of the sun.

Phenomenon. Any natural appearance, may be properly called a phenomenon. The term however is usually applied to something new or extraordinary.

Physical. Belonging to material nature.

Physics. The science which treats of matter, or of nature in general.

Piston. That part of a pump or other engine which is made to fit into a hollow cylinder, or barrel; and to move up and down in it, in order to create a vacuum to raise water, or for any other purpose.

Plane. A perfectly flat surface.

Plumb-line. A line or cord with a leaden weight suspended by it, used by masons and builders for the purpose of finding a line perpendicular to the horizon; the weight being always vertical, or attracted towards the centre of the earth.

Pneumatics. From the Greek *pneuma*, air. A branch of natural philosophy which considers the phenomena of the air; the laws according to which that fluid is condensed, rarefied, and affected by pressure or gravitation.

Poles. The extreme points of the axis of motion in the earth, or any other sphere.

Ponderosity. Weight, gravity, heaviness.

Power. In physics it is the moving principle of an engine, the force which we apply to give effect to any mechanical instrument. That which moves the instrument or machine is the power, whether it be wind, water, weights, springs, horses, men or steam.

Prism. A solid, triangular or wedge-shaped, glass instrument, used to refract light, and separate its differently colored rays.

Prismatic colors. The colors of the rainbow, or of the solar spectrums.

Projection. The direction or motion given to a body by some power, other than that of gravity, acting upon it.

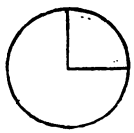
Projectiles. Bodies impelled by projection, or a projectile force. When a stone is thrown from the hand, it is by a projectile force.

Pulley. One of the compound mechanical powers. It consists of a wheel, turning upon an axis, with a cord passing over it.

Pyrometer. An instrument for measuring intense degrees of heat.

Q.

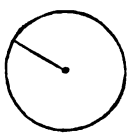
Quadrant. Ninety degrees, the half of a semicircle, or the fourth part of a circle.



R.

Radiation. An emission of rays.

Radius. Is a straight line drawn from the centre of a circle to its circumference. The plural of radius is *radii*. Radii of the same circle are equal to one another.



Rainbow. An appearance in the atmosphere occasioned by the decomposition of solar light, in its refraction, and reflection, in passing through drops of rain. The bow can be seen only in a part of the heavens opposite to the sun, when that luminary is near the horizon, and when his rays pass through drops of falling rain.

Ratio. The relation which one quantity bears to another.

Ray. A single line of light, emitted in one direction, from any luminous point.

Reaction. Every body, whether in a state of motion, or of rest, tends to remain in such state, and resists the action of any other body upon it, with a force equal to that action. This resistance is called its re-action.

Receiver. A glass vessel, being part of the apparatus of the air-pump, from which the air may be exhausted. The condenser has also a receiver, and gas-receivers are much used in Chemistry.

Reflection. The bending back of rays of light, or sound from a surface. The angles made by the rays of light, and waves of sound with a perpendicular to the surface, in coming and going, are equal.

Refraction. The bending or breaking of a ray of light in passing through media of different densities, as in going from air into water or glass, and the contrary.

Refrangibility. Capacity of being refracted. Light is decomposed by the prism, because its component parts are refrangible in different degrees, by the same refracting medium.

Repulsion. A tendency in particles, or in masses of matter, to recede from each other. It is the reverse of attraction.

Resulting Force. The force resulting from the joint effects of a number of forces.

Retina. Is the set of nerves which are spread at the back of the eye, to receive the excitement of the rays of light, for the purpose of forming the images of visible objects, and of conveying the idea of them to the mind, by means of the optic nerve.

Reverberate. To beat back, to resound.

Rotation. Rotary, the act of whirling round or revolving like a wheel.

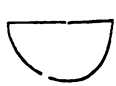
S.

Satellites. Moons revolving around planets. Secondaries.

Screw. One of the compound mechanical powers, of great force when the lever is applied to it.

Sector. The Sector, *a*, is the figure included between two radii of a circle, and is less than a quadrant.

Segment of a Circle. A figure bounded by a line, and the arc of a circle.



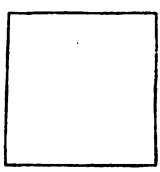
Semi-circle. Half of a circle, or 180 degrees.

Sine. The perpendicular drawn from the extremity of an arc, to the diameter of a circle.

Siphon or *Syphon.* A bent pipe through which liquids are conveyed. A siphon will empty a vessel of its contents, by the atmospheric pressure, a vacuum being first formed.

Sky. The vast expanse, or space, in which the heavenly bodies are situated. Its blue appearance is supposed to be owing to the particles of which the atmosphere is composed, reflecting the blue rays and absorbing the others.

Belonging to the Sun.
Spectrum. The colored image of the sun, refracted through
sm.
Particles of matter formed into a cohesive mass.
us bodies. Those bodies which are capable of being put
a state of vibration so as to emit sounds.
Is a motion or excitation of the air perceptible by the ear,
produced by vibrations from sonorous bodies.
room; the boundless region which contains the universe.
: *gravity.* The relative weight of bodies of different spe-
when the same bulk of each is taken. Water has been
en as the standard of comparison. If we say the specific
ity of a body is six, we mean that it weighs six times as
1 as the same bulk of water. If a body has but half the
fic gravity of water, it is expressed decimally, thus, .5.
A globe. A solid body, whose surface, in all parts, is
lly distant from the centre.
id. A body approaching to the form of the sphere, either
ig or oblate. The earth is an oblate spheroid, being flat-
l at the poles. A spheroid is formed by the revolution of an
se about one of its axes. Spheroids are sometimes irregular
eir forms.
A curve like a watch-spring. It may be circular, as a
wound about a round stick, or elliptical, as a wire wound
t an oval stick.



. A figure having four equal sides, and
right-angles.

. From the Greek word, *statos*, standing still. That branch
echanics which considers bodies submitted to the influence
rces which are in equilibrium.
n. A layer, or bed; the plural is *strata.*
d. To be opposite. That is, the arc or curve which is
site to the angle formed by two radii of a sphere, is said to
nd that angle.
ces. Space extended in length and breadth. The surface of
figure.

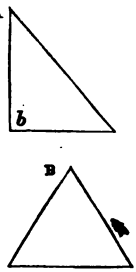
T.

nt. A right line touching a curve, but not cutting it. (See
r, b.)

Telescope. An instrument by which distant objects may be distinctly seen, by being greatly magnified in appearance and their images brought near to the eye.

Thermometer. An instrument by which the temperature or degree of heat of any substance is ascertained.

Transparent. Allowing the rays a free passage through. The reverse of opaque; the same as *diaphanous.*



Triangle. A figure enclosed by three sides, and which has three angles. If it has one right-angle, as *b*, (see triangle A,) it is called a *right-angled triangle.* If the sides are all equal, (as in triangle B,) it is called an *equilateral triangle.* The three angles of every triangle, contain 180 degrees, or are equal to a semicircle.

Tube. A cylindrical pipe.

U.

Undulation. A wave.

V.

Vacuum. Space void of matter. In a *receiver*, exhausted of air by the air-pump, there is said to be a vacuum.

Valve. A little door. A lid or cover so formed as to open a communication in one way, and close it in the other. A part of a pump which opens to admit the passage of a fluid in one direction, and closes when pressed in the other, so as to prevent the return of the fluid.

Vapor. Steam and exhalations.

Vertical. The direction of the plumb-line.

Vesicles. Small hollow spheres of water.

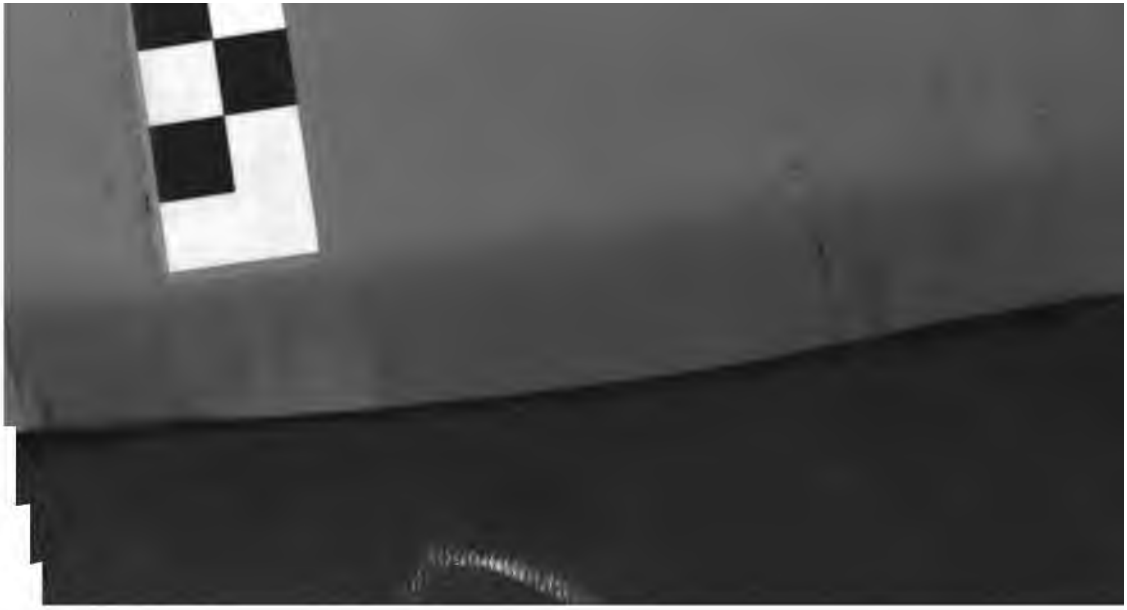
Vibration. Motion to and fro.

Visual ray. A ray of light coming from any object to the eye.

W.

Wedge. One of the compound mechanical powers. When driven with the mallet, it is of great force, rending solid masses of wood or stone, and lifting great weights.

Wheel and axle. One of the compound mechanical powers, in very extensive use. Cranes for raising weights, the wheels and *pinions of* clocks and watches, and windlasses, are among some *of the many* modifications of this power.



[redacted]

1322